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Number 4

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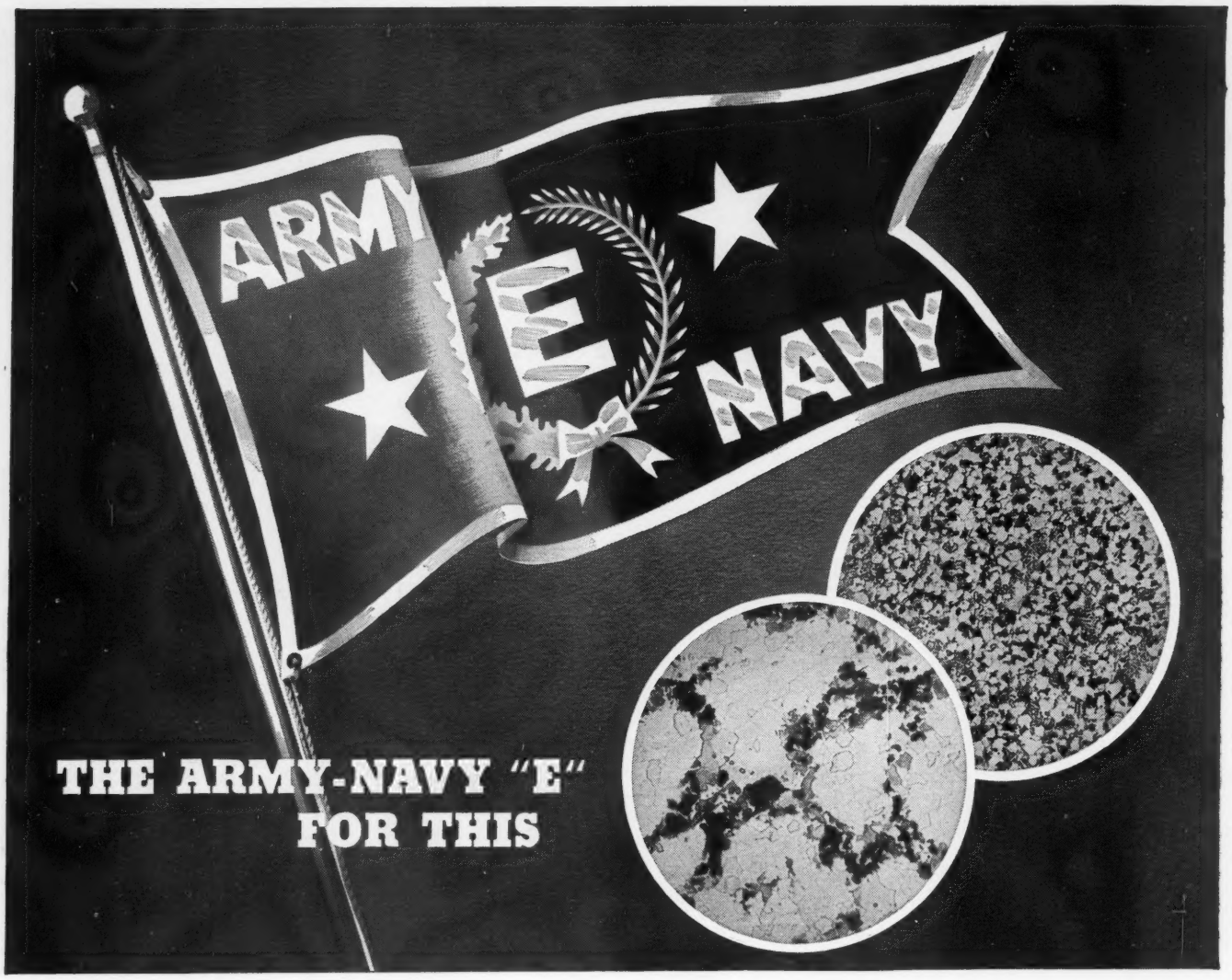
THIS IS M. I. T. . . . .

PRESENTING

CIVIL ENGINEERING



On September 5th, 1942, our Mine and Mill at Climax, our Research Laboratory at Detroit and our Conversion Plant at Langeloth, Pennsylvania, were given the Army-Navy Production Award. Since then the award has been twice renewed. The two-starred flag we fly represents a full year of contribution to the war effort recognized by the Army and Navy.

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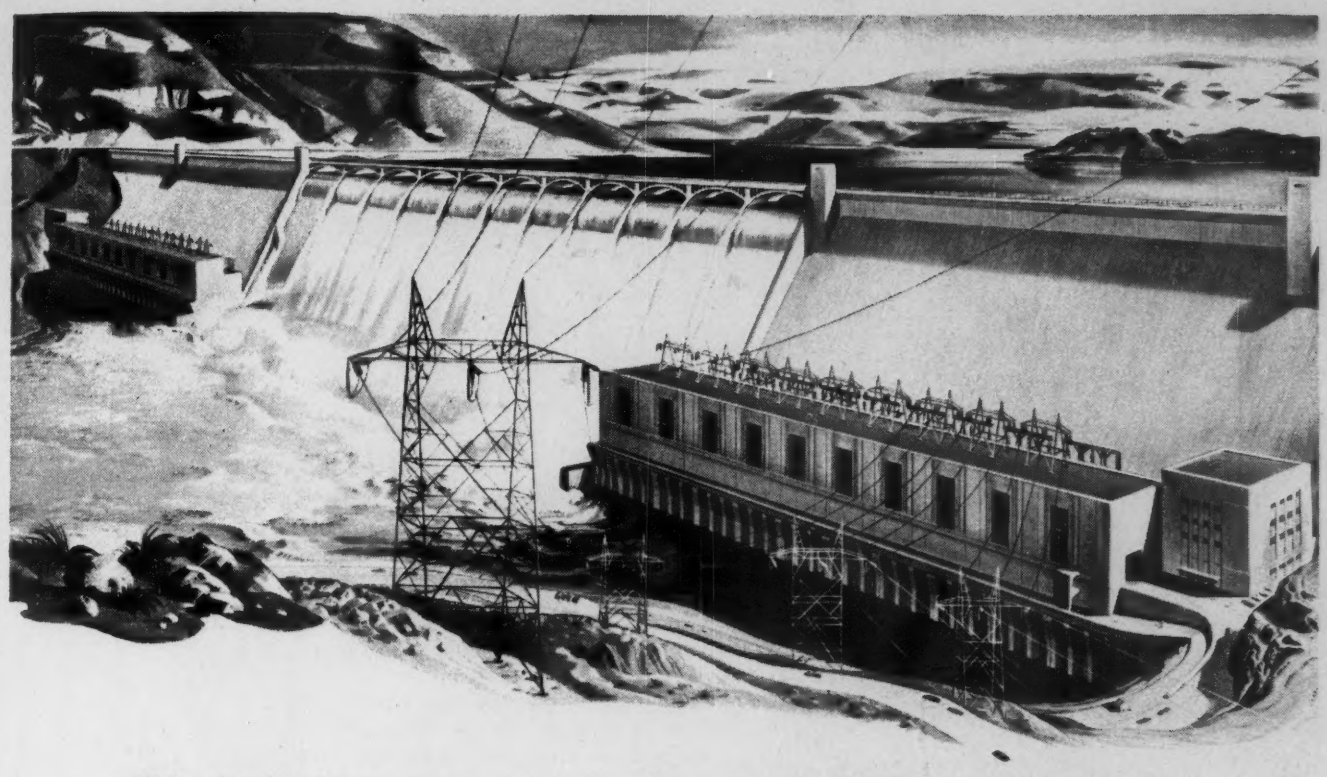

Westinghouse generators make power for a nation at war . . .

From the world's largest water-wheel generators at Grand Coulee Dam—from Westinghouse steam-driven generators in power plants throughout the nation—flow billions of kilowatts of electric power to turn the wheels of America's war industry.

Westinghouse combines the power of a thousand human skills . . .

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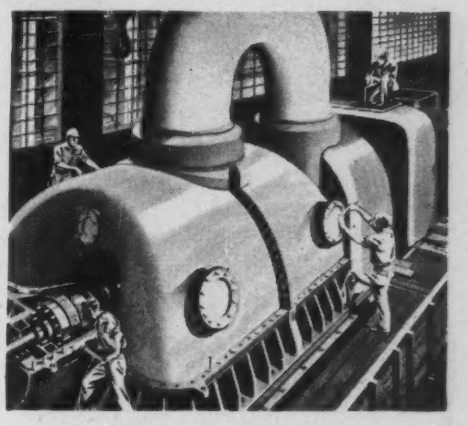
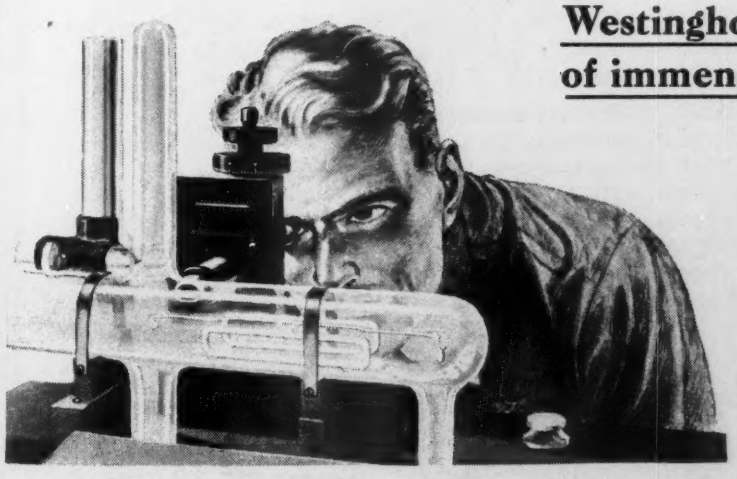


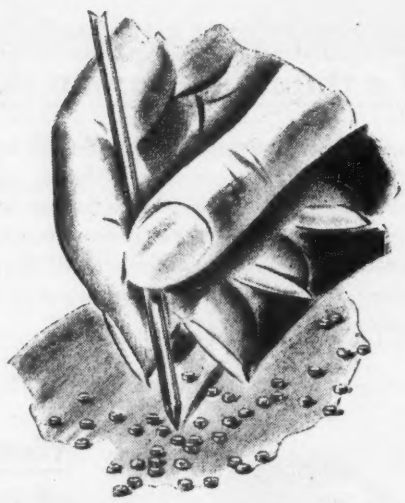


Westinghouse contributes the power of immense new knowledge . . .

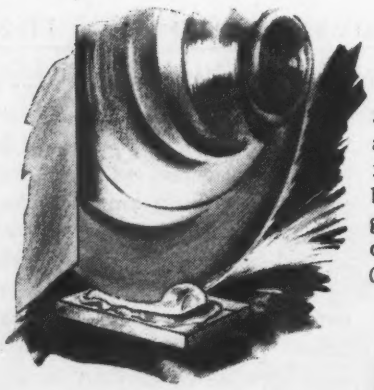
When the incredible weapons born of wartime research are reforged for peacetime service, the daily miracles that electricity will perform are certain to create new and finer standards of living . . . while the cost of electricity continues to decrease as our nation's power-generating capacity continues to increase. Westinghouse Electric & Manufacturing Company, Pittsburgh, Pa. Plants in 25 cities—offices everywhere.

The synthetic sapphire that becomes a precious jewel...

1. High over Berlin on the instrument board of a bomber, these synthetic sapphires become the most precious jewels in the world. They're man-made jewels for instrument bearings. Without them, no bomber could drop its load with accuracy, no warship could navigate. Before Pearl Harbor most of these synthetic jewels came from abroad. But today industry is mass producing its own with the help of diamond blades and polishing compounds such as made by Carborundum.



2. Man-made sapphires are created by fusing aluminum oxide. To turn the rough boule into a bearing requires more than 100 precision operations, including cutting, grinding and polishing. No tolerance over 0.0003 in. is permissible. One of the best abrasives for producing a sapphire bearing is the diamond. So diamond grinding compounds by Carborundum are widely utilized.



3. War has given enormous impetus to the art of grinding. In industry, you may find operations which might be done better with abrasives. Carborundum engineers will be glad to consult with you on any such problem. The Carborundum Company, Niagara Falls, New York.

CARBORUNDUM
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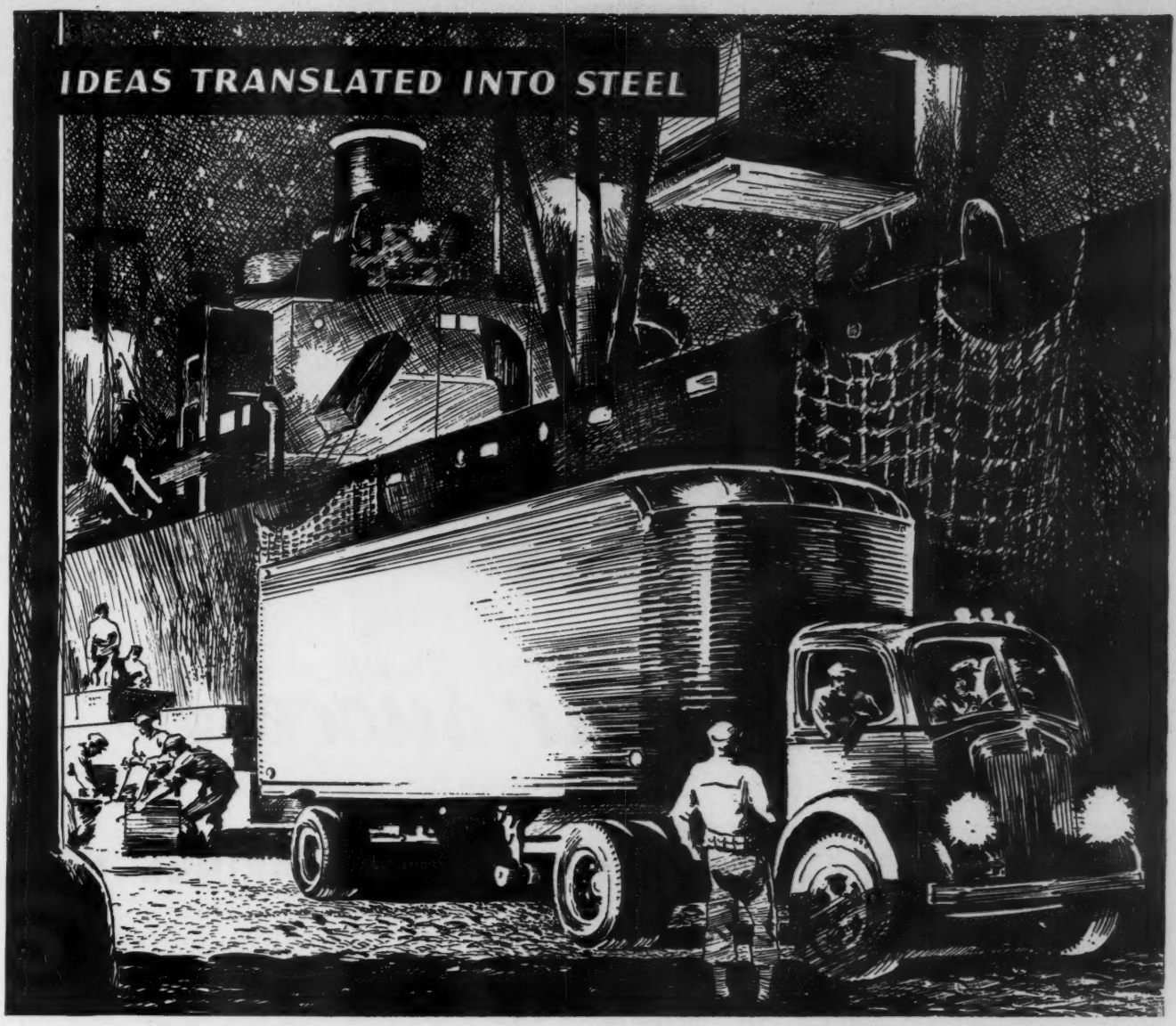

The order came at five . . . special shipment must reach North River by 2 a.m. . . . freighter sailing before sun-rise. Within an hour the huge trailer was loaded. Moments later it was under way and sixteen tons of urgent equipment rolled through the war plant gate to reach Pier M forty minutes before schedule . . . a run of 280 miles.

These gleaming truck trailers do the "impossible" in war deliveries because they are built of ideas as well as stainless steel; ideas that slash dead-weight, save fuel, increase the pay load; ideas that bring new measures of strength and stamina, and enable highway carriers to supplement the colossal task of the railroads, with thoroughly dependable, on-time service.

Budd originated these streamlined truck trailers. They were designed by Budd engineers—built by workmen skilled in converting steel to the needs of modern transportation. When war interrupted, Budd was expanding facilities to meet the demand created by their economy and performance.

Now the Budd plants are working one hundred percent on airplanes, naval structures, ordnance and other materiel for the Army and Navy. We have built thousands of bodies for army trucks. The skills and facilities so readily adapted to war production are being perfected. New ideas are born. The future will find Budd active in the new era of travel and transport.

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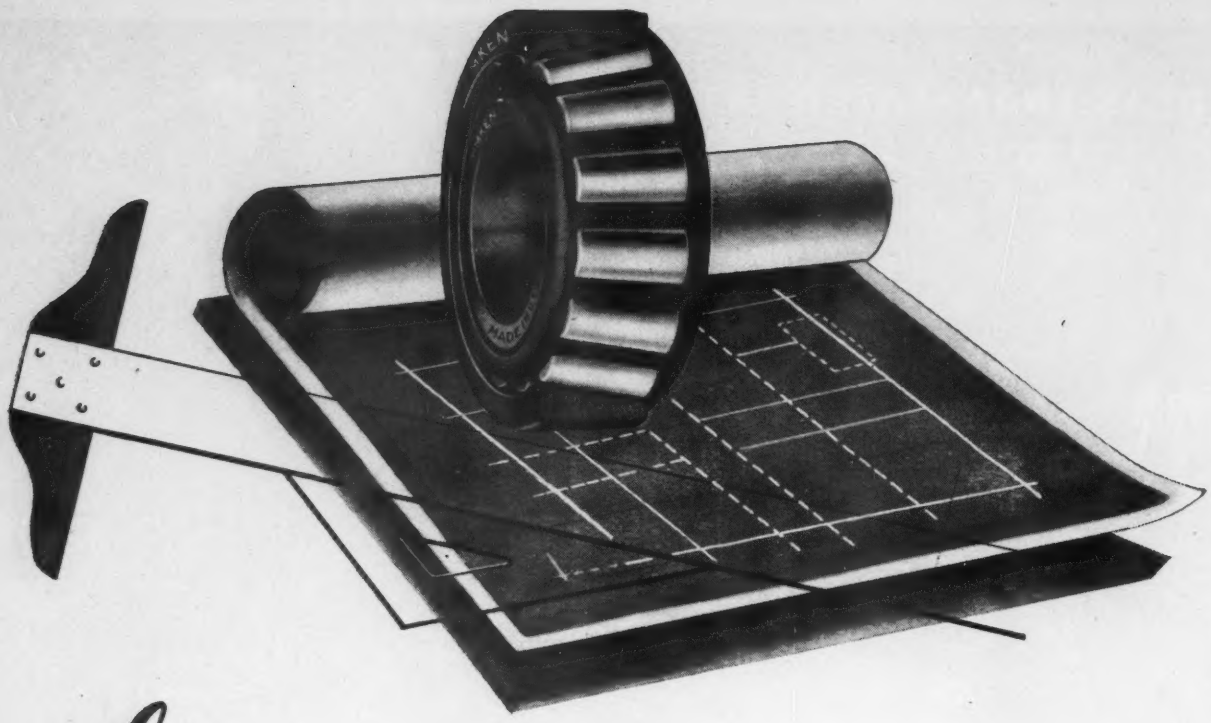

for post-war success

LEARN TO KNOW YOUR BEARINGS NOW

YOU may not get into this war, but there will be another tough struggle awaiting you when Victory has been won and the job of reconstruction begins. You probably will graduate right into the midst of the most severe competitive situation our country ever has known.

Then, as a full-fledged engineer, you will have the responsibility of keeping your company's products ahead of those of competitors by giving them greater speed, precision and endurance; lower operating and maintenance costs.

That's where your specialized knowledge of Timken Bearing design and application will pay dividends; for you will be in position to meet any and every bearing condition with complete protection against friction; radial, thrust and combined loads; and misalignment of moving parts.

Begin to acquire that knowledge now—while there still is time. Timken engineers will be glad to help you. The Timken Roller Bearing Company, Canton, Ohio.

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TAPERED ROLLER BEARINGS

THE TECH ENGINEERING NEWS

PROFESSIONAL JOURNAL OF THE UNDERGRADUATES
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

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THIS IS M. I. T.

CIVIL ENGINEERING

By PROFESSOR THEODORE B. PARKER

Head of Department of Civil and Sanitary Engineering, M. I. T.

CIVIL ENGINEERING, one of the oldest branches of the engineering profession, has recently received an extraordinary stimulus from the development of new ideas, new materials, and new methods of construction. These recent developments result partly from normal progress in all branches of engineering, and in part from a greatly accelerated improvement caused by the pressure of world events. Whatever the cause, the result has been an increasingly interesting field of endeavor.

Civil engineers continue to provide the stationary structures which support and house the various implements of our civilization.

These structures include familiar types, such as bridges, dams, buildings and docks, which were formerly relatively simple in character. Progress in the arts and sciences and the greater complexity of industrial operations, however, have greatly increased the magnitude and complexity of the structures required, and have caused the development of completely new types.

With the tremendous growth in importance of these works, has come a great increase in the number of technical problems involved. The impact of such developments upon the character of civil engineering practice has been most remarkable.

Magnitude alone has important effects upon engineering requirements. Since every really large project is necessarily of economic importance, its various parts also assume importance proportionate to their size and cost. Details which on an ordinary job receive only routine treatment, on a larger project require careful analysis and attention.

More complete mathematical analysis of our structures is leading to greater accuracy in stress determination, and consequently to greater economies through the use of higher loadings. With better knowledge of actual stress conditions it is possible to reduce the "factor of ignorance" and to work materials much closer to their ultimate strength.

Whenever a large project is built, a proportionally great number of people must be employed, and among these employees there must be found the various special skills required to cover all phases of the work. The organization of a large number of individuals into an effective working unit is an extremely interesting undertaking, which requires administrative work of a very special character.

Durability, or rather the relative durability of structures, has assumed new importance, owing both to the large investments involved and to the wide variation in the lasting qualities of different materials.

This is because in most projects, even those involving considerable mechanical equipment, the supporting structures usually represent a large proportion of the investment, making fixed charges on these structures an important consideration in the financial picture. Depending on the primary purpose to be served, the durability of structures can vary from almost unlimited "life" in works of a permanent nature, to very short periods in certain types of military construction.

Problems of durability are of two kinds: those having to do with the essential character of a material such as concrete, and those related to the protection and preservation of less durable materials such as timber and frequently steel. Where several million yards of concrete or several thousand tons of steel are used in a single structure, it is obvious that the preservation of these materials from early disintegration is of the utmost importance.

A noteworthy example of the introduction of new ideas into the field of Civil Engineering is the development of soil mechanics. The use of soil for foundations, for embankments, and for a multitude of everyday uses, has been a commonplace for thousands of years. It is only recently that engineers have attempted a scientific analysis of soil as a structural material. While this new science is far from being perfected, it has already opened the door to a wide range of most interesting possibilities.

Construction methods show a rapidly growing tendency toward the greater use of mechanical equipment, with a reduction in the proportionate amount of direct labor on the job. The effects of this factor upon engineering practices are felt in several directions.

The greater use of equipment becomes increasingly economical on large projects, and is further encouraged by rising labor costs. Continual improvements in such equipment and the development of new types afford a prospect of almost indefinite reduction in costs by means of further mechanization of construction operations.

The engineering planning for a modern construction project must, therefore, include not only the design of the permanent structures, but the layout and details for the construction plant and equipment. Such plans for construction must be made well in advance of the start of the project, so as to facilitate deliveries of the necessary materials and equipment.

The effect of construction mechanization is felt even in the early stages of design. The general type of the structures is usually determined on an economic basis, depending on cost estimates which must make provision

for the methods of construction contemplated. Where different design types require the use of different construction plant and equipment, cost estimates to be reliable must include allowance for the cost of the construction operations appropriate for each design.

The obvious result of this closer interrelation between design and construction planning is to make more desirable a closer relationship between the engineering and construction organizations. There are ways of maintaining such a close relationship when the construction is done by contract, but it is clear that there are great advantages in having engineering and construction under the same direction.

In the past, the materials used for simple structures were relatively simple themselves. Much of the early construction in this country was frankly temporary in character, and the materials, such as they were, were readily obtainable and easily replaced. Most of the early designs were based on empirical methods which under the circumstances gave reasonably practical results.

For modern permanent works on a large scale, much more careful scrutiny must be given to the materials of construction. These are of two classes: natural materials found and used at the site, and those manufactured, transported, and erected. In the first class are earth, rock, timber, and water, and in the second the great multiplicity of materials and equipment fabricated from metals and similar products.

For the successful discovery and use of the natural materials, a knowledge of practical geology is essential, in addition to the techniques of utilization which are only now being developed. For intelligent employment of the products of our rapidly changing and developing industries, it is necessary to have at least a general knowledge of manufacturing processes.

Recent trends in Sanitary Engineering have in general paralleled those in the Civil Engineering field. Major problems have been created by great concentrations of population and industry, leading in turn to projects of vastly wider scope than the single water supply or disposal plant. Consequently whole metropolitan areas are treated as units, and entire drainage basins are included in a single development.

The technique available to the sanitary engineer has developed correspondingly. Mechanization has already supplemented the gravity flow of liquids; it is now replacing labor in operative processes and in moving and conditioning materials.

The structures and plants designed and built by civil and sanitary engineers require not only a proper start in life, but intelligent and continued operation and maintenance. There is now an appropriate field for graduate engineers in this kind of work, and in all the varied fields of supply and manufacture which serve construction enterprises.

A large number of the structures designed today by civil engineers are built to house appliances or equipment of a highly technical character which are provided by other branches of the engineering profession. Some knowledge of these other branches is essential

(*Continued on page 127*)

Arterial Parkway System, New York City. Henry Hudson Parkway intersection at 79th Street along Hudson River

FACE POWDER GOES TO WAR

By ROBERT M. GOULD, 6-45

General Manager, The Tech Engineering News

THE face powder that your best girl uses has been put to work for the war effort. The base of this powder is talc, the softest of minerals, which is also the base of one of the hardest ceramic materials, steatite. Steatite has become the leader in the high frequency insulation field because it combines the desired high mechanical strength and electrical properties such as high electrical resistance and low dielectric loss which are stable over a wide frequency range.

Most insulating mediums other than steatite are applicable under certain conditions only, since their electrical and mechanical properties are often affected by moisture, temperature, mechanical load and frequency.

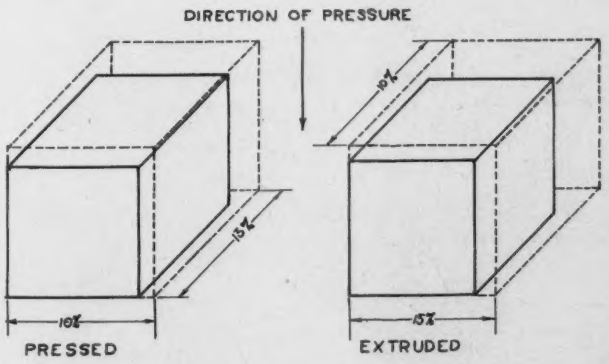
Talc is a hydrated magnesium silicate whose theoretical formula is $3\ MgO \cdot 4SiO_2 \cdot H_2O$. As the material is found in nature it has a flaky appearance, the flakes appearing greenish to gray when in a mass but colorless when viewed separately. The material has a greasy soap-like feeling. Because of this, talc is often called soapstone. The talc used in steatite must be extremely low in conducting metals such as iron, copper, etc. The lime content must be small because lime acts as a rapid flux, lowering the firing range of the material.

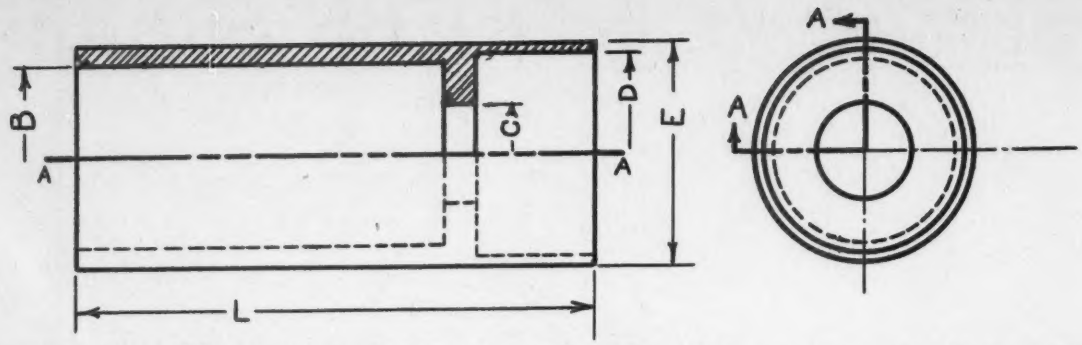
The properties of different talcs must be taken into consideration when composing a body. Ceramic bodies shrink during the firing; therefore tools and dies are constructed with allowance made for this definite shrinkage value. The small tolerances required by steatite parts necessitate extreme accuracy of the fabricating tools. This raises the cost of the tools. Therefore tool life is an important item in the manufacture of steatite insulators. The raw materials and their supply must be kept constant so as to insure the same shrinkage and accuracy of the finished part. Pressed and extruded parts may have a minimum tolerance of ± 1 per cent or ± 0.005, whichever is the greater. A typical body consists of 90 per cent talc, five per cent ball and china clay and five per cent potash feldspar. The clay gives plasticity to the mixture. The feldspar is used as a flux, potash feldspar being used rather than soda feldspar, since K_2O causes far less power loss than Na_2O. The feldspar imparts to the final product about 10 per cent glass, resulting from the action upon the silica in the talc.

The formula permits a very small addition of clay; therefore organic binders such as glue, flour and waxes in small amounts are added to improve the workability of the body. These binders burn out during the firing operation and do not affect the electrical properties of the finished product.

After the body is standardized, actual manufacture is begun. The raw materials, all finer than 325 mesh, are accurately weighed and mixed together (they will pass through a screen with 325 holes per square inch, so fine that it can hold water if the bottom has not previously been wet) in a giant mixer with rolling steel or stone mullers. The mixing continues dry until a homogenous mixture is obtained. Then the binder and the proper amount of moisture are added. This amount depends upon how the article is to be formed. There are four possible methods: dry press, wet press, extrusion and casting. The first three are the ones most widely used. For dry pressing, the body is ground so that 99.5 per cent will pass a 16 mesh screen. One to

Shrinkage during the firing operation is one of the main problems in tool design. Average shrinkage is shown in the diagram. Pressed pieces shrink about 10 per cent perpendicular to the direction of pressure, and about 13 per cent along the line of application of pressure. Extruded pieces shrink about 10 per cent along the line of pressure, and from 15 to 20 per cent perpendicular to the direction of pressure.





Machined extruded part. This part is extruded in a long, thin cylinder. It is cut to proper length, L, and then drilled with a combination drill, cutting both holes C and D. Hole B is then drilled. This part could be molded, but is so small that molding would be expensive.

two per cent moisture is added to the dry press mixture. A wet press mixture has from two to 16 per cent of water. The extrusion mixture has about 17 to 24 per cent moisture.

Wet and dry press articles are molded in the same type of presses. Anything from small hand presses up to large hundred-ton hydraulic or automatic presses are used. During the pressing operation the material is compressed in a ratio of about 2.5 : 1. Thus if the final product is to be about 10 cubic inches, the amount of powdered material needed is 25 cubic inches. The pressure needed for dry pressing is 4—5 tons per square inch and 400—600 pounds per square inch for wet pressing. Another factor to be considered is the shrinkage in the direction of pressing and perpendicular to the direction of applied pressure.

Extrusion methods can be compared to the action of a toothpaste tube. A pressure is built up in the tube and a bar of leather-hard material is forced through a small opening. In extruding steatite, a pressure of 400 pounds per square inch forces a column of the material through a nozzle. Pieces up to six inches in diameter can be extruded, either solid or hollow. The extruded pieces are allowed to "dry" for at least a day, before any machining is done.

Almost any machining operation can be accomplished on either extruded or pressed pieces. Threads can be applied to the surface of a piece. Holes not in the line of pressing cannot be pressed and have to be drilled. Molded holes and drilled holes can be tapped to precise dimensions. To obtain closer dimensional control, certain pieces are prefired, called "bisque fired" to about 1000 degrees Centigrade and then machined.

The glaze can be applied to the article either before firing, in which case both glaze and body are fired together; or after partial firing in the case of bisqued ware. The glaze can be sprayed, hand painted or dipped. A piece that is to be fully glazed can be dipped. A part that is to be glazed on all except one end is sprayed. If only some areas are to be glazed, the object is either hand-painted, or it is sprayed with the areas to remain unglazed being covered. A good steatite glaze is composed of 70 per cent potash feldspar, 20–25 per cent talc with a high lime content and five to 10 per cent clay.

By the time the article is ready for firing it has passed through many tests. The pressed pieces have been inspected for overall size, exact placing of holes, weight, etc. All machining operations are inspected, threads being inspected for depth, pitch and root diameter.

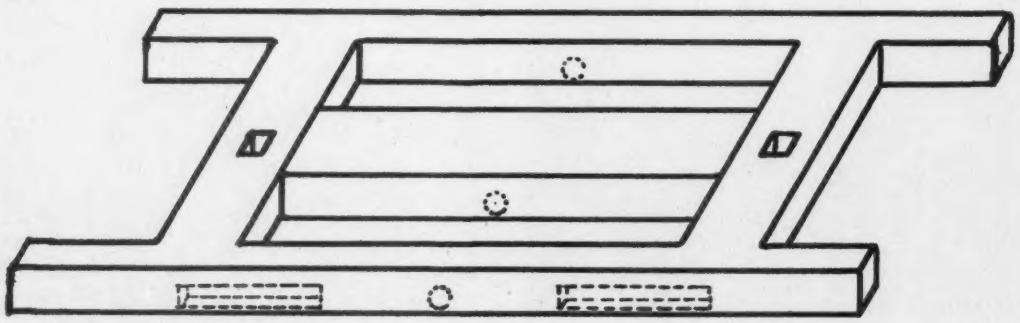
The article is fired in a tunnel kiln. The heating cycle varies from six hours to twenty-four hours. A normal heating schedule is:

Heat increase to vitrification	6–7 hours
Soaking period	2 hours
Cooling period	6–12 hours

In the first period the temperature is gradually increased until the heat of vitrification is reached. This is the point at which a "glass" is formed. At this point the magnesium and silicate go into solution, forming a solid solution of a clear "glass." During the soaking period, the temperature must be held constant at the vitrification point, which is between 2150° F. and 2450° F., depending upon the body composition used, and must be held to close limits. If the temperature varies more than 10 to 15° F. above the point, blistering and eventually liquefaction occurs; thus no precision would be obtained upon the finished piece. At a temperature of more than 10 to 15° F. below the point, no "glass" would be formed completely. As the piece cools, crystals of clinoenstatite, a clear pure form of the hydrated magnesium silicate, are formed. If the cooling

(*Continued on page 134*)

Machined pressed part. All holes, indentions, etc. in the line of pressing can be molded. The dotted holes and indentions cannot be molded, and so are machined.



SERVO—A MODERN SLAVE

By C. E. GROSSER '31

Assistant Professor of Mechanical Engineering, M. I. T.

SERVO is the common abbreviation for a class of automatically controlled machine systems that are more properly called servo-mechanisms. Other names that have been applied to them are: closed cycle systems and slave-mechanisms. The latter is highly suggestive of their function, which is to replace and to augment human labor not merely with the ability to develop power or to perform a given sequence of work operations usually thought of as automatic, but in a manner which involves a degree of intelligence to perceive the effects of variations in external conditions and to make the necessary corrections in their behavior to accommodate themselves to the changes under which they must work. They are truly machines equipped with the equivalent of a brain with which to "think" and "nervous system" with which the "brain" may perceive the changes in environment as well as to convey its impulses of control to the "muscles" which do the work required of them.

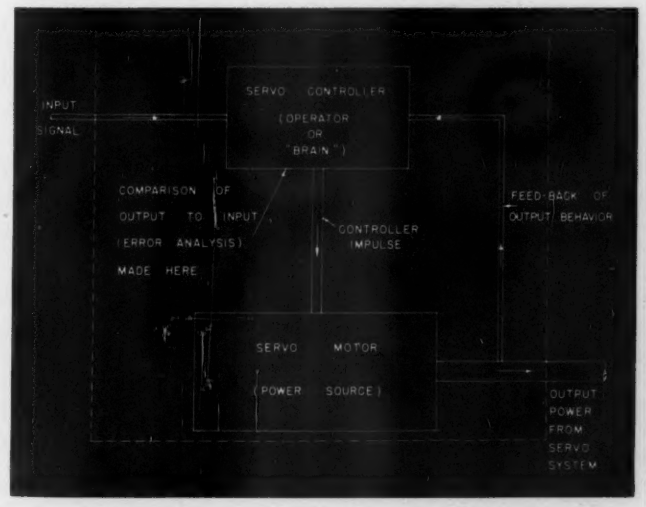
The analogy to the human system is not to suggest that machines are in existence which will duplicate human behavior in all its aspects. However, it does mean that many mechanical operations of a routine and essentially simple nature may now be delegated to machines with the assurance that they will be carried out automatically, with precision, within prescribed limits; in much the same way as they might be by a mechanically trained person who had unlimited: strength, sensitivity of perception (of specific kinds) or rapidity of response.

The closed cycle system as a theoretical entity is not new, having been described almost a hundred years ago in mathematical terms. Also, as will be observed in the descriptions which follow of various kinds of servo-mechanics, simple forms have been in use since man invented the capstan. However, the art of the exact designing of servo-mechanics is quite new, having been developed wholly within the current generation. It has developed very rapidly during the past decade and plays a most important part in the automatic control of many machines of war in the current conflict. Undoubtedly it will be considered one of the most important developments of the present age, comparable with the discovery of steam power. As its potentialities unfold it bids fair to release mankind from countless tasks of mechanical labor which now consume most of its time and attention.

A servo-mechanism may scientifically be defined as a power amplifying device which will perform an output function at high power level in response to an imposed directive signal, meanwhile constantly measuring the error between its output performance and the input signal, and correcting its behavior to reduce the error. The definition covers an extremely broad classification of systems not necessarily purely mechanical, but combinations of all kinds of elements including: mechanical, electrical, hydraulic, pneumatic, optical, thermodynamic, etc., so long as the functional performance is self-corrective.

The particular portion of a servo-mechanism which performs the output function desired is called, in the technical parlance, a servo-motor. This is the "muscle" in the human analogy. It may be, for example, a manufacturing machine, a heating system, a searchlight drive, a steering gear, an electric motor, or almost any mechanism imaginable. The balance of the system which (1) receives the directive signal, (2) measures the error in performance as compared with the signal, and (3) controls the servo-motor in a manner to correct the error in its operation is called the servo-controller. Here

Fig. 1. Schematic diagram of a general hydraulic servo-circuit indicates how the driving element is actuated by the difference between the input and output of the servo-mechanism.



we have the "brain" and "nervous" system. A schematic diagram of a typical servo system indicating the component elements is shown in Fig. 1.

A familiar and special kind of controller is found in "regulators." Examples are: speed governors for motors and turbines; thermostatic controls for heat treating furnaces and heating systems; automatic repeater compasses for ship and airplane steering; tension regulators in continuous metal strip, wire, or paper manufacture. They are characterized by the fact that they are set up with a constant input signal, and act to hold some physical quantity at constant magnitude or to permit variation only over a limited range. The power amplification in such regulated systems may consist in the transformation of relatively feeble instrument impulses into controlled uniform operation at high power level.

Even within the restricted category of regulatory servo-mechanisms there has been a tremendous release of manpower from routine functions in domestic as well as in industrial pursuits. Their application is quite well understood, governed by common and relatively simple mathematical expressions. It is being continually extended in all directions.

Those regulatory servos were naturally the first automatically controlled systems to come into being, because of their inherent simplicity of function and ability to operate satisfactorily in crude forms within wide limits of design variation.

The next stage in development, which occurred in comparatively recent times, was the introduction of variable signals at the controller input. This opened up a vast new panorama of automatic control fields and introduced many forms of what is popularly known as "booster" operation. Easily recognized examples of the latter are found in steering and brake boosters for heavy vehicles, such as trucks and busses; airplane surface control boosters; torque amplifiers for increasing the power output from instruments, etc. With a "boosted" or servo equipped truck steering gear a light finger-tip operation of the steering wheel will cause an immediate and proportionate movement of the massive front wheels and their mounts, against large resistance factors such as road and mechanical friction and inertia. Such a set-up is illustrated in the accompanying photographs (Fig. 2) of a truck equipped with a hydraulic cylinder as a servo-motor attached to the Pitman arm of the steering gear, controlled by a valve controller

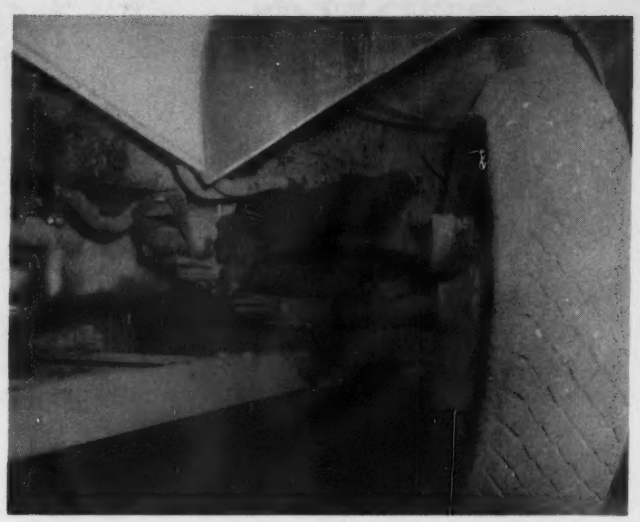


Fig. 2. Servo-mechanism used on the Boston Elevated's snow fighters

which is in turn actuated from the steering column. The power supplying the servo-motor comes from an engine-driven oil pump. The circuit is generally illustrated in Fig. 4, being a typical hydraulic valve-controlled positioning servo.

Brake boosters operate on a similar principle, wherein a light foot pedal pressure is instantly reflected in a proportionately large force on the brake mechanism. The power medium here is most often vacuum or air pressure.

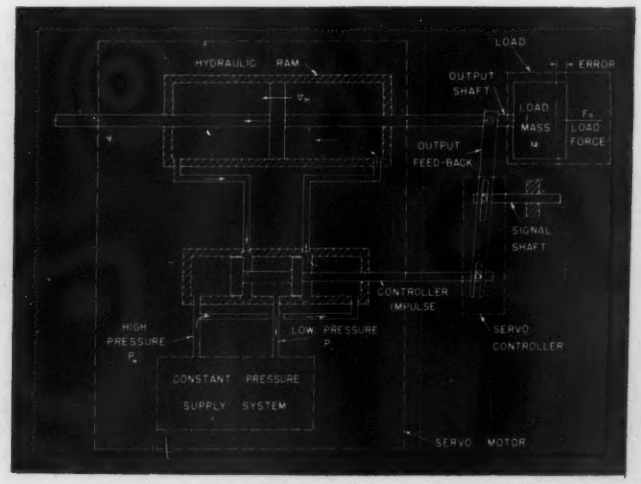
The airplane surface control booster system using the same basic hydraulic circuit as used by the truck steering booster is shown in Fig. 5. The feed-back from the rudder position is so arranged that the pilot actuating the controls may "feel" a certain proportion of the control surface resistance in order that he may sense air conditions. It is again an example of the simple hydraulic valve controlled servo-mechanism.

Many other forms of "boosters," or in more scientific language, torque and force amplifiers, are in use; making manual operations less fatiguing, rendering them more accurate and precise, making possible the use of larger and larger machines under human direc-

(*Continued on page 126*)

Fig. 3. One of the Elevated's giant trucks which is steered with a servo-mechanism

Fig. 4. This circuit is the same as that shown in Fig. 3 but with the four-way valve opened in response to a displacement of the signal shaft



ALUMNUS OF THE MONTH

VANNEVAR BUSH

President, Carnegie Institution of Washington

Director,

Office of Scientific Research and Development

Although he spent his early college years at another school, Vannevar Bush has made such an impression on M. I. T., both through his contributions to the Institute's high reputation as a result of his personal achievements and services and as a result of his brilliant career in American science and industry, that TECH ENGINEERING NEWS is honored and proud to present him as our Alumnus of the Month.

Vannevar Bush was born in Everett, Massachusetts, on March 11, 1890. His father was the Reverend Richard Perry Bush, but Vannevar realized at an early age that his career was not to be the clergy. He entered Tufts College in the Class of 1914 and graduated president of his class and his fraternity, having worked his way through doing such jobs as washing dishes. At Tufts, once when his mathematics professor was sick, Bush took over the class. He taught it so well that he came back in 1914 and 1915 to teach the mathematics course. However, he graduated in Electrical Engineering, and was promoted to Assistant Professor of Electrical Engineering in 1916. Although only out of school in 1914, Dr. Bush came to M. I. T. in 1916 as Associate Professor of Electrical Power Transmission. It was at this time that he completed his studies for Doctor of Engineering. This is as high as he ascended the ladder of scholastic achievement — he never progressed past Doctor of Engineering — yet today he is the Director of the Office of Scientific Research and Development, and twenty-five thousand Ph.D.'s, including Dr. Compton, President of the Institute, are working under him.

Dr. Bush's stay at M. I. T. constitutes one of the more noteworthy phases of his career. While working for his degree he made a study of the undergraduate curriculum in Electrical Engineering. Under his supervision it was revised to its present status, and today it represents one of the best courses in Electrical Engineering in the world. His whiplash mind manifested itself more than once during his stay at Tech. For instance, when he took his first sail in a Tech dinghy, within thirty-five minutes after he had set sail he had devised an automatic steering device for the dinghy. It was with such a mind as this that he invented and built the three-ton differential equation analyzer, an instrument which solves the most difficult equations in a few minutes.

The same time that he was Associate Professor of Electrical Power Transmission at M. I. T. earning his degree, Dr. Bush was Consulting Engineer for the American Radio and Research Corporation. Previously, upon graduation from Tufts, he had worked for General Electric; following this was a job as Naval Inspector. During the World War he assisted in developing submarine detector devices with the United States Navy. After the war he continued as a Professor at M. I. T., until in 1923 he was made Dean of Engineering and Vice-President of the Institute. He served in this capacity until 1938, and in 1939 he was called to Washington to take the Presidency of the Carnegie Institution of Washington. This $33,000,000 foundation conducts research throughout the world on subjects ranging from Marine Biology to the Mount Wilson Observatory in California. At the time of his appointment President Compton said, "Dr. Bush is so eminently qualified for his new position and the post is of such great influence and opportunity in the field of science and human welfare that his collegues at Technology are unanimous in their approval of his selection."

In 1941 Dr. Bush was appointed by President Roosevelt to the first of two offices he was to hold in administration of the war, when he was named Chairman of the National Research Committee. It was after this, however, when he was appointed as Director of the Office of Scientific Research and Development of the Office of Emergency Management, that he assumed a position which was to be one of the most important and most ably administered jobs which he ever held. The OSRD has come up perhaps less than any other of the wartime bureaus for criticism, so ably has it been handled and organized. Under Dr. Bush's leadership research centers have been established at all leading American universities. The speed and efficiency with which this agency has responded to requests for emergency war equipment is almost historical. Problems come in and are solved over night. Back of it all is the brilliant mind of Dr. Bush, and after the victory he will have many ideas to present to the war-tired world.

Dr. Bush is an author and the winner of many medals, including the Holley Medal of the A.S.M.E. for 1943. He is a member of nearly all the American engineering and scholastic societies and fraternities, and is a director of the American Institute of Electrical Engineers and a Regent of the Smithsonian Institution. Besides being Director of the OSRD, he is Chairman of the Joint Committee on New Weapons and Equipment of Joint United States Chiefs of Staff. As such, he is the only civilian who has ever sat in on a War Council of the United States Army.

An appropriate closing for this sketch is this excerpt from the address given by Professor Timbie of the Institute when Dr. Bush left M. I. T. for the Carnegie Institution. Professor Timbie said, "Tech has always had the reputation for having an expert in every branch of science, and it is too bad to lose him."

CHEMICAL WARFARE

By MAJOR PERLEY D. BAKER

Chemical Warfare Service, Army of the United States
Assistant Professor of Military Science and Tactics, M. I. T.

BEGINNING with World War I a large number of articles, authentic and otherwise, have been written upon the subject of chemical warfare. This has had a tendency to make the layman chemical warfare conscious and has probably produced an impression in the minds of some that the employment of chemicals in warfare was a new development. Actually, history contains an appreciable number of instances where the accomplishing of a mission was brought about, or aided, through the use of chemical agents.

The first recorded use of chemical warfare occurred in the Siege of Plataea, in 431–429 B.C., when the Spartans saturated wood with pitch and sulphur, and burned it under the walls of the city in an attempt to choke the defenders and make the assault easier. In 1701 A.D., Charles XII of Sweden produced a smoke screen by burning damp straw. Under the cover of this screen he successfully crossed the Dirna River and assumed battle positions in the face of superior forces before the enemy realized what had happened. During the siege of Sebastopol in 1855 Admiral Lord Dundonald submitted to the British Admiralty a scheme for the use of sulphur for the reduction of the Russian forts. However, the plan was rejected. There is evidence that sulphur was used during the War of 1812 and also during the siege of Charleston in the Civil War. While it is possible to add to this list and also to show that other agents, e.g., chlorine, were given consideration, this brief outline will suffice.

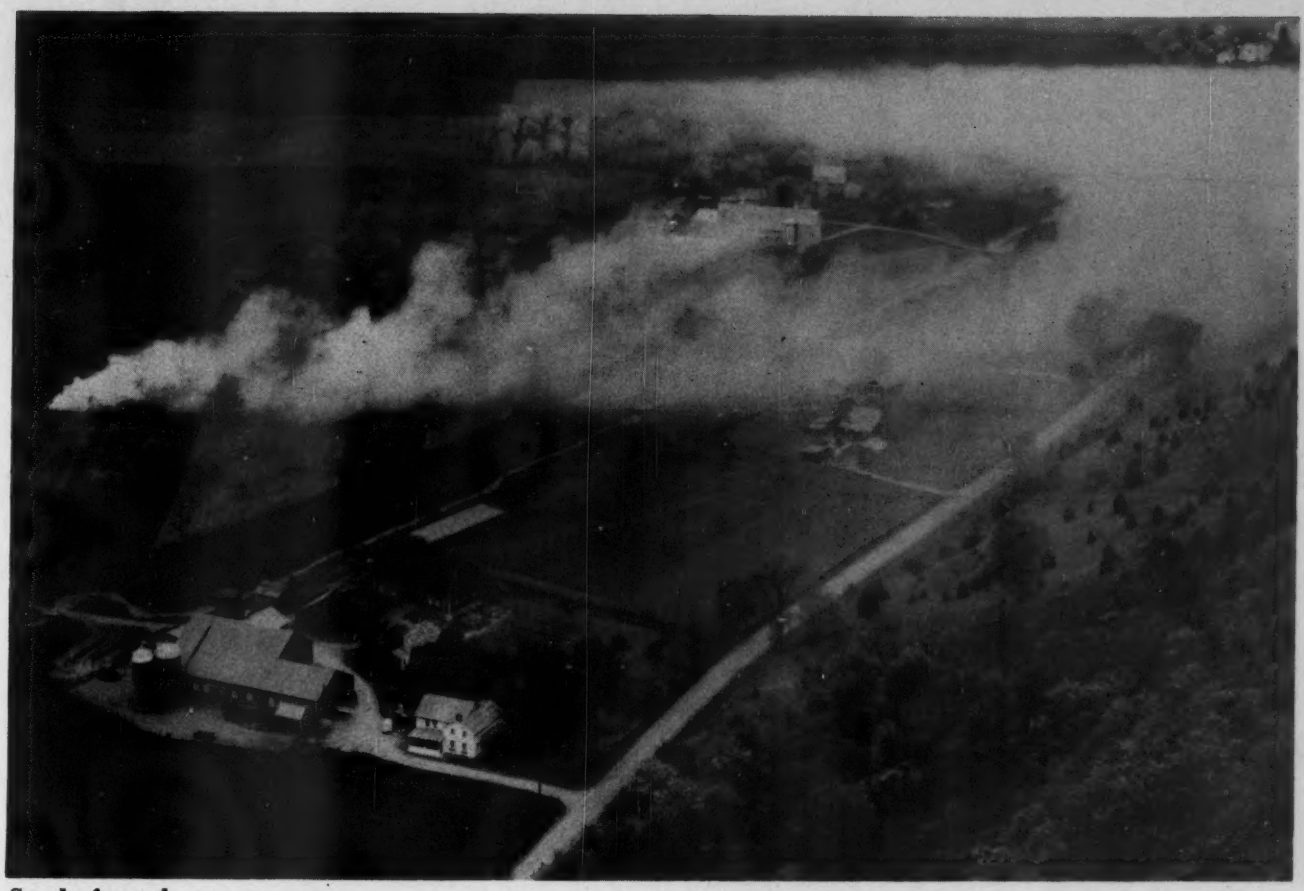
Soldier garbed in protective clothing using the three-gallon decontaminating apparatus on a gassed vehicle

Training Aids Division, Edgewood Arsenal

During the eighteenth and nineteenth centuries the rapid development of chemistry brought forth new and toxic compounds. Many of these were considered suitable for use in warfare and their discoverers recommended such employment. That there was serious consideration of these possibilities by the War Departments of various countries is evident from the following instances. At the Hague Conference in 1899 a proposal was made that prohibited the use of projectiles whose main object was "the diffusion of asphyxiating or deleterious gases." France and Germany were among the nations ratifying this agreement, but the United States was not included in the list. At the Hague Congress of 1907 an article was adopted forbidding the employment of "poisons or poisonous weapons."

Prior to the war France had developed a 26 mm. cartridge filled with ethylbromoacetate and designed to be used against small openings such as loopholes. The French maintained that since this agent was a lacrimator it did not violate the Hague Convention. The Germans claim that this was used against their troops at various times during the early stages of World War I. The Germans themselves admit using chemical agents in 1914 and early in 1915, but these attacks apparently had little effect. These attempts to introduce chemical agents were a natural consequence since the war had become stabilized, and it was only a matter of time before a method would be developed that would be effective against trench warfare.

It is difficult to visualize a more effective weapon for this purpose than chemical warfare. The very nature of a gas, with the proper characteristics and under favorable conditions, makes it suitable for reaching down into trenches and dugouts. Technique and tactics of warfare have been modified through the centuries through the requirements of necessity. Thus it was logical that a scientifically trained man should real-



Smoke from the new generator — *General Electric Company*

ize the possibilities, and it is reported that Professor Nernst suggested the use of gas by the German Army. The preparations for the gas attack at Ypres were made under the direction of Professor Haber. It took some time to complete the preparations and then the attack could not be launched until conditions were favorable. During this time information relative to the pending gas attack reached the Allies through deserters, prisoners, and espionage agents. No importance was attached to these reports by those who had the high authority, and as a result the attack on April 22, 1915 was a complete success. If the Germans had made suitable preparations to take advantage of the opportunity open to them, there is a good possibility that the French and British fronts could have been separated.

After this both sides developed methods for protecting their troops and sought new agents and new methods for projecting chemical agents. In December 1915, the Germans introduced a mixture of chlorine and phosgene, but the Allies were prepared, for this time they did not neglect the information that they had received through intelligence reports. Other chemical agents were introduced, and on July 12, 1917, the Germans used mustard gas for the first time. In an attempt to use a vesicant that was less persistent the Germans tried out ethyldichlorarsine in 1918 but found this agent much less vesicant than mustard gas. This agent was also easier to protect against than mustard gas.

Dr. W. L. Lewis, at the time a captain in the United States Army, first prepared lewisite in 1917. Due to manufacturing difficulties it was not produced until the latter part of the war and this proved to be too late for its employment against the Germans. Since the war the Germans claim to have prepared and manufactured lewisite before Dr. Lewis had developed his synthesis. If this is correct they made an error in not using it.

The majority of the chemical agents mentioned above had been known for some time. Chlorine was prepared by Scheele, a Swedish apothecary, in 1774. Phosgene, carbonyl chloride, was made by an English chemist, John Davy, in 1812. In 1848 the English chemist, Stenhouse, made chlorpicrin, trichloronitromethane. Another Englishman, Guthrie, prepared mustard, beta, beta prime-dichlorodiethylsulfide, in 1860. This was investigated by the German chemist, Victor Mayer, in 1866. Of the other more important agents used during the war, both brombenzyl cyanide, a lacrimator, and diphenyl chlorarsine, a toxic smoke, had been prepared in 1881. The latter compound was introduced by the Germans in an attempt to penetrate the gas masks of the Allies but was not successful due to the method used to disperse it.

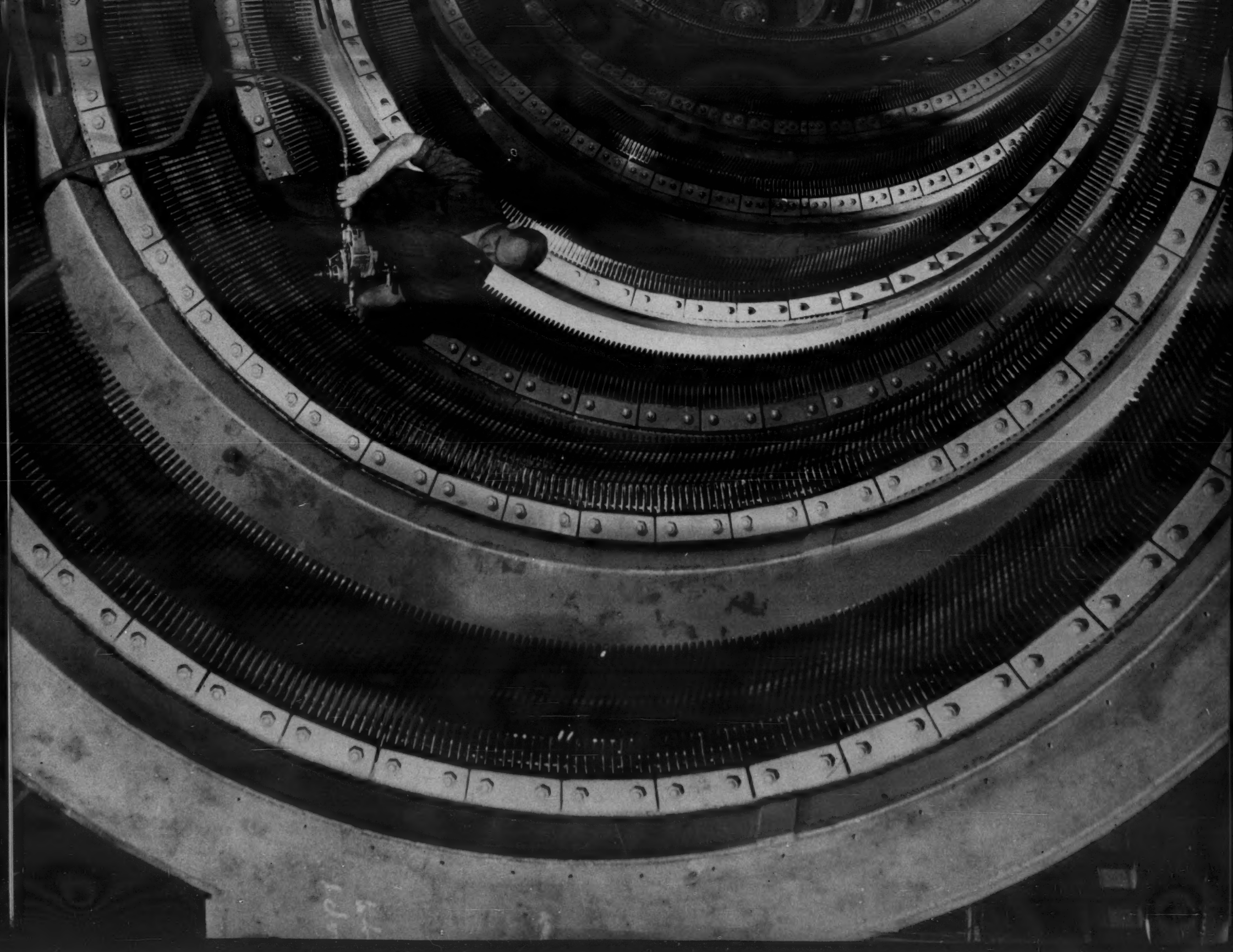
During the war the propaganda used by the Allies against the Germans produced the impression that chemical warfare was barbarous. No phase of warfare can be considered humane, but viewing the statistics of the war relatively, chemical warfare was the most humane weapon employed. Of 78,663 gas casualties in

(*Continued on page 130*)

On the following pages:

WHIRLPOOL OF POWER

There's a power potential of nearly 65,000 horsepower in this scene at the Schenectady plant of the General Electric Company. The four sixteen-foot frames in the foreground are part of 6,000-horsepower motors, while the three seventeen-foot ones behind are rated at 10,000 horsepower. In the background are rotors for a 10,000-horsepower, 850,000-pound twin motor which will drive a rolling mill in what will be the largest steel plant west of the Mississippi. *General Electric Company*



THE BIRTH OF A BOMBER

By STANFORD A. FINGERHOOD, 2-46

Make-Up Editor, The Tech Engineering News

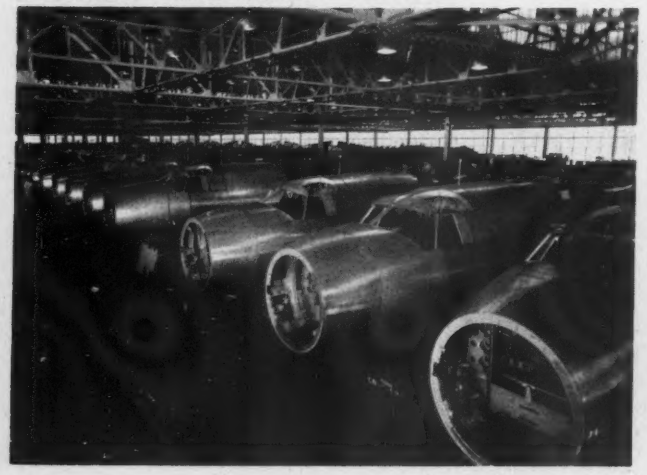
Pictures courtesy the Glenn L. Martin Company

THE industrial demands of modern war are tremendous. The United States is now producing more than seven thousand planes per month, and proposed figures for next year are even higher. This demand for large scale production of aircraft has resulted in adoption of many of the mass production techniques of the automotive industry, and huge bombers now roll off the assembly lines in the same way that automobiles did in peacetime. This story traces the career of an Army bomber from its birth on paper till its initial baptism of fire.

Bombers are born on the battlefield. The Army, through contact with the enemy, decides that a new type bomber with a certain speed, range, ceiling and armament capacity is needed. Type specifications outlining the desired characteristics are sent to the manufacturer, and the bomber is on its way toward reality.

The engineering department of the company studies these specifications, and makes a general layout of the "air frame." The air frame has to carry all the offensive, defensive, and auxiliary equipment of the plane, and at the same time deliver the required aerodynamical performance given in the specifications. The weight of the frame is one of the designers' main problems, because every added pound means one pound less for fuel and bombs.

B-26 bodies — nose section.



Meanwhile, in the experimental shops, a full-sized wood and cloth mockup of the plane and several smaller wind-tunnel models are being built. From the full-sized model it can be seen whether enough room has been provided inside the plane for the crew to operate efficiently, and the aerodynamic characteristics of the smaller models are tested in a wind tunnel.

The completed and detailed plans of the air frame are returned to the Army along with all data on the performance of the models, and if they are approved a contract is signed, and the bomber goes into mass production. The first step is to create a "manufacturing breakdown." This is done by a committee composed of the designers, consultant specialists, shop superintendents, and production experts. The manufacturing breakdown shows, in general, how the plane is to be put together in the shop, what the order of assemblage will be, and what tools and materials will be needed.

The building of the bomber is usually broken down into four major assemblies: the nose, the center section of the fuselage, the tail sections, and the wing sections. However, before production can start, there is still much work to be done. The engineering department has the job of making layout drawings of the major assemblies, and then breaking them down into sub-assemblies, and sub sub-assemblies, and making detailed drawings of all these parts. Then every drawing must be checked by stress engineers.

Meanwhile, men from the procurement division have been looking over the layouts and determining what materials will be needed, and the tool department starts to work designing any special tools that will be needed in manufacture.

As each layout plan is completed it is given to the Army for approval, and then officially handed over to the production department. Expediters are sent all over the country to get scarce material and procurement items such as nuts, bolts, cleco clamps, forgings, castings, and extrusions. The department is, at the same time, busy obtaining priorities and shipping space, placing orders for sub-contracted items, and locating factory space.

The tool department draws up "operations cards," explaining the use of equipment and how to build the parts for each layout, while the engineering department must make working blueprints and templates from the

detailed part drawings. For each bomber coming off the assembly line thousands of blueprints, several tons of them, are needed. They are now made by a new photographic process, which is an Allied secret, and represents a considerable saving of time.

Before actual work on the plane can start, production schedules must be arranged, conveyor lines routed, and floor space so laid out that the parts travel a minimum distance between operations. Then the first work on the construction of the plane itself starts, as thousands of men and women go to work turning out detail parts. The detail parts go to storerooms where they are kept till enough parts accumulate for the assembly line to start working. They are then fed in a continuous stream to the machines that will use them. Some of the parts, however, are packaged and sent as spares to Army replacement depots on the fighting fronts.

The assembly line is the heart of the bomber plant. Three different types of material come into the plant: sub-contracted items, procurement parts, and raw materials. They must all pass a rigid inspection before work is started with the sheet metal entering the departments where they are formed into detail parts.

Most of the metal goes first to the sheet metal department where it is cut to size. Formed parts were formerly shaped by drop hammers, but a great saving in time has been effected by the use of crank and hydromatic presses for this type of work. Stamped parts are turned out by punch presses, and then the parts go to the welding shop for all necessary work. Aluminum and steel castings are machined in the machine shops

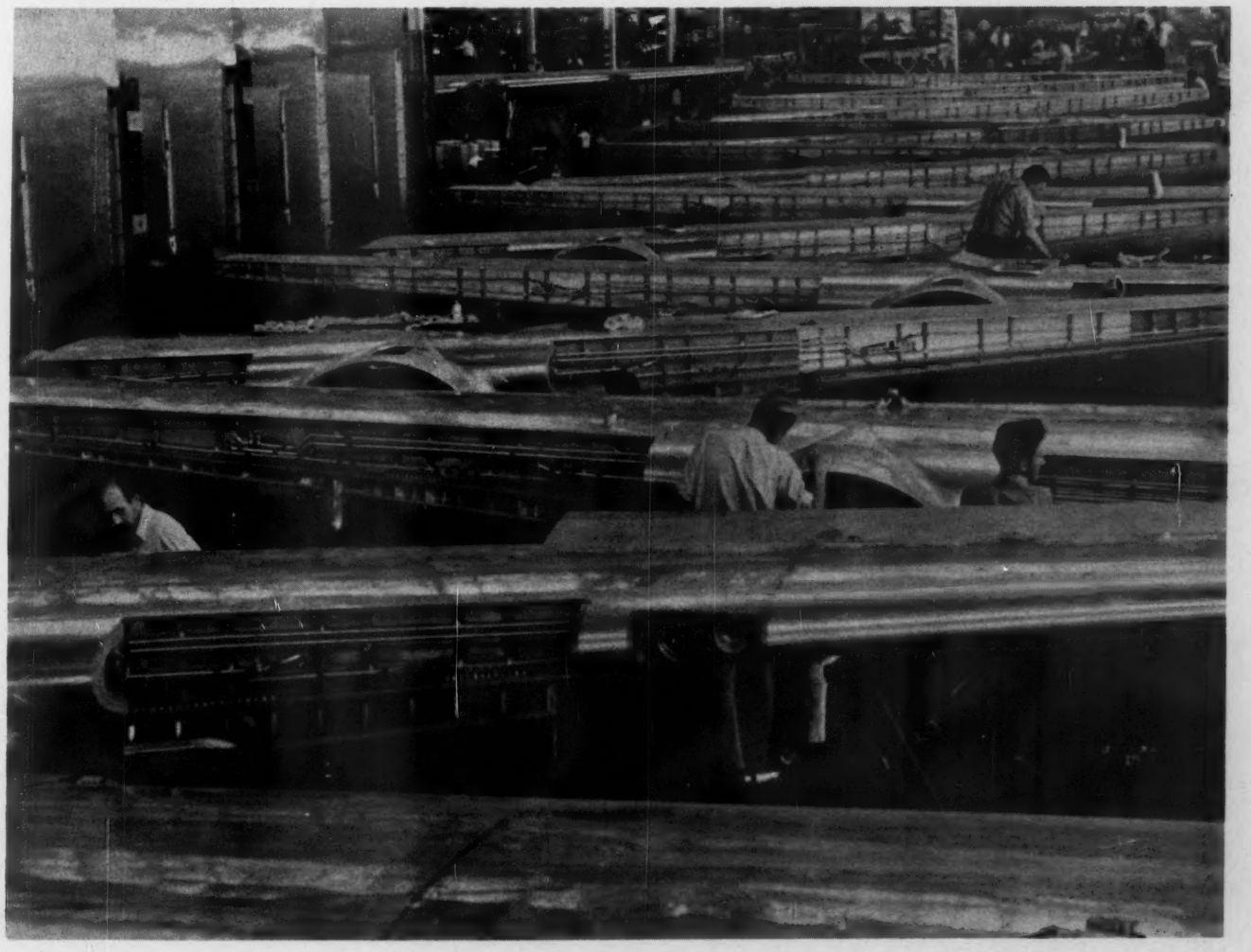
Engineering design — PBM-3

and then the steel parts are treated and finished, usually by plating with cadmium metal. Most of the aluminum parts get an anodyzing treatment that helps adhesion to paint and inhibits corrosion.

The detail parts are assembled to form sub-assemblies such as bulkheads, instrument panels, bomb bay panels, and wing leading edges. The sub-assemblies are

(*Continued on page 136*)

B-26 outer wings



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PABST MAKES POST-WAR PLANS

On December 8 there appeared simultaneously in newspapers all over the country an announcement by the Pabst Breweries that should arouse the interest of students, soldiers, backyard politicians, writers, and the general run of amateur and professional politicians and world-reformers the country over. A lot of people have a lot of ideas and have wanted very much to do something about our economic and social system after the war.

Here is the opportunity of a lifetime for them all, a chance to reform the world and make a tidy sum at the same time.

What was offered by the Pabst people is this: they will hold a contest for the best essay presented on the problem of Post-War Employment by a citizen of the United States, whether civilian or soldier. To quote the advertisement directly, the goal of this contest is: "In recognition of the critical importance of the Post-War Employment Problem; to stimulate intelligent planning for the lives and the futures of Americans everywhere; to foster and encourage constructive thinking for the fullest measure of employment after victory." The contest is to be judged by such experts in the field as Clarence Dykstra, President of the University of Wisconsin; Wesley Mitchell, Professor of Economics, Columbia University; Beardsley Ruml, Chairman of the Federal Reserve Bank of New York, and inaugurator of the Ruml 'Pay-As-You-Go' Tax Plan so recently considered by the Congress, and A. F. Whitney, President of the Brotherhood of Railroad Trainmen. The winning essays are to be turned over to 'responsible officials of the Government' and any other agency — public or private — which concerns itself with the problems of Post-War Employment." We have seen some pretty ambitious contests, everywhere from awards for the prettiest designs one could cut from a certain newspaper to a prize given for guessing what famous man a cartoon represents. This, however, is one of the most sensible contests that have yet been proffered to the public. Instead of filling out the sentence, "I like Sudso Soap more than any other soap because—" in twenty-five words or less, this contest offers a first prize of $25,000 for the best answer to what in effect is the question, "What Shall We Do About Employment After the War?" in two thousand words or less.

How this contest will boost Pabst sales is a rather obscure point. More than anything, perhaps, it will put the name Pabst before the public. On the other hand the contest may be more an instrument to stimulate more discussions on post-war plans, at which consequently much Pabst beer will be drunk. Looking at the matter seriously, Pabst stands to gain very little more than the headache of reading thousands of lengthy papers on Post-War Employment, a job which yours truly, who has to read only five papers of under two thousand words per month for T. E. N., would not accept for love or money.

The results of this contest will be of interest to everyone who would have any interest in holding a job in industry after the war. Undoubtedly this will be one of the most important of all post-victory problems. This will not mean too much to the Tech man theoretically, for as before, there will be a constant demand for good engineers after and during the war. But it will be a problem for the many people who do not have the Tech man's passport into business. The ex-serviceman is perhaps the greatest example of this problem, and any plan will have to include him. Many companies already have plans for taking care of their war employees in giant conversion operation and switching to peacetime operations. As the advertisement suggests, thought on the subject will be stimulated and crystallized into some kind of concrete idea, which will be available to anyone to whom it could be of use. This in turn will give rise to more ideas, the result of which will unquestionably take form into useful suggestions.

What we are trying to drive at in this editorial is not necessarily a beatification of the Pabst Company. It is more an appeal for more post-war planning of this type; less of the obnoxious suggestions set forth by individuals anxious for recognition of some form or another. Our first problem is of course winning the war and then planning can run rife. This is a subject upon which every American should give a thought, for no one wants a repetition of the last war, its "Roaring Twenties" followed by the catastrophic depression of the thirties. T. E. N. realizes this vital need for constructive consideration, and intends to include articles on the Post-War World in future issues. Our world of the future will be what students like us at Tech make it. It is up to us.

C. B. B.

. . . engineered at Western Electric

IN a split second this enemy plane will be blasted from the skies by a shell from one of our anti-aircraft guns.

How is it possible? Just think of the mathematical problems involved in hitting a plane going 300 miles an hour 20,000 feet up . . . when it takes the shell 15 seconds to get up there and in that time the plane has gone more than a mile! Besides, the shell curves in its flight. Wind blows it. Gravity pulls on it. Even the weather affects its velocity.

The greatest mathematician could never solve these problems in time to hit the plane. But engineers at Bell Telephone Laboratories and Western Electric have designed and produced a Gun Director—*an electrical brain*—that solves them instantly!

It plots the plane's height and course—continuously matches the curved path of the shell to the path of the plane so the two will meet. It aims the guns—even times the fuse to explode the shell at the exact instant.

Putting the 3300 parts of this electrical brain into production called for the development at Western Electric of many special tools, machines and manufacturing methods. Mechanical, electrical and industrial engineers cooperated with chemical and radio engineers in this work.

Making the *electrical* Gun Director is just one of many interesting assignments in Western Electric's vast war production job.

Till the last enemy plane is knocked down, buy all the War Bonds you can!

Western Electric

IN PEACE...SOURCE OF SUPPLY FOR THE BELL SYSTEM.
IN WAR.. ARSENAL OF COMMUNICATIONS EQUIPMENT.

LUFKIN MICROMETERS
Lufkin micrometers are the ideal tool for quickly and accurately checking machined parts.
Because of their sturdy construction Lufkin micrometers stand up well under constant use. Because of their design they are easy to adjust and easy to read. See them at your dealer's and write for complete catalog.
LUFKIN
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TAPES · RULES · PRECISION TOOLS

SERVO—A MODERN SLAVE

(*Continued from page 116*)

tion with no greater problems of operation than are encountered with their smaller predecessors. More importantly these devices permit the substitution for human operators of instruments exerting no more than "flea power" to furnish the guiding signals which direct the labor performed by the servo-mechanism. Boosters are in general single stage amplifiers of energy, transforming for example a small energy signal impulse of displacement in the steering servo into a proportionate displacement at the output, and supplying whatever power is necessary to accomplish the latter. The amplification may however be carried out in several stages in cascade, the output from one servo serving as the input to a following, with the response from the final output returning eventually to the controller of the first servo in the chain.

An interesting type of mechanical booster which is very old, but of which potential applications have not been widely appreciated, is the simple friction capstan. This is shown schematically in Fig. 6. It consists essentially of a power-driven capstan drum turning at constant speed with one or more turns of a rope wrapped around it. An operator pulling on the end of the rope marked T_1 may cause the servo to raise or lower a large weight by simply signalling to it by hauling in or paying out the rope, in the process exerting very little force. The amplification ratio in this case is given by the expression:

$$\frac{T_1}{T_2} = \frac{1}{e^{\mu\theta}}, \qquad (1)$$

where: ϵ = logarithmic base number,
μ = coefficient of friction between drum and rope,
θ = angle of wrap (in radians).

The expression should be familiar to all students of elementary mechanics.

The capstan servo has been used on marine vessels for hauling anchors, rigging ropes; by well-drillers to raise and lower their tools. It has also been applied to a limited extent to amplify the output of instrument indicators, in machine tool drives, and is the basic principle in the operation of the self-energizing brake.

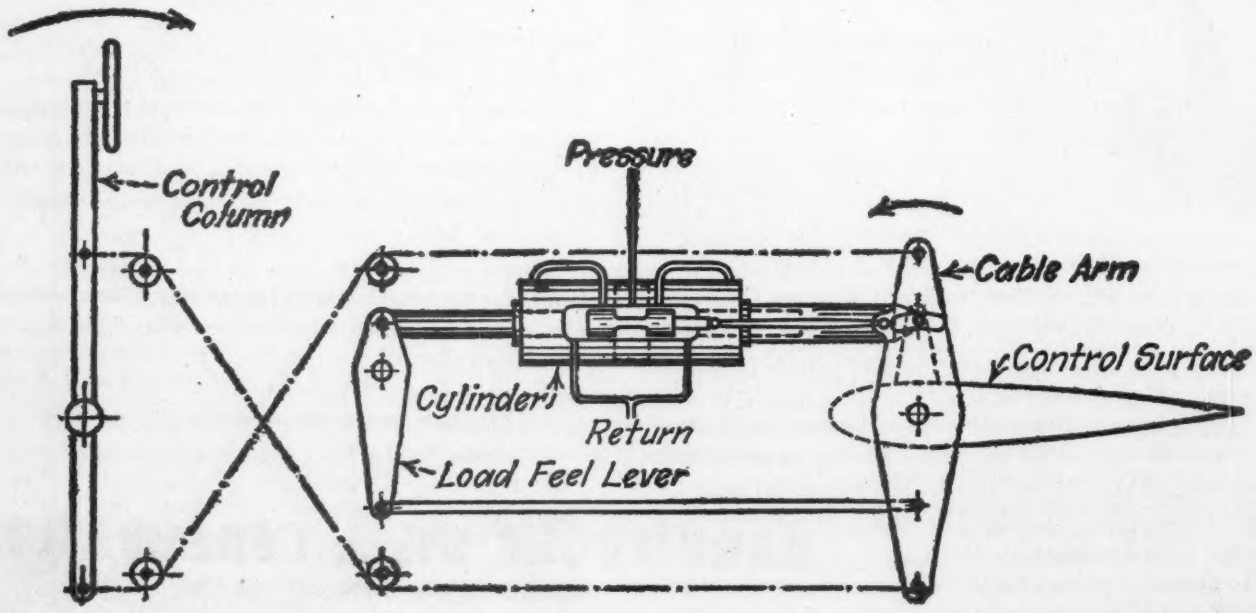
Recently developed variable input servos are the automatic profile-following machines by which machining operations may be performed in accurate correspondence with the position of a pointer moving over a model surface with very light pressure. These include profile grinders, profile milling machines, forming lathes, and shape flame cutters.

Many automatic recording instruments and calculating machines contain servo-mechanisms of one kind

(*Continued on page 128*)

Fig. 5. Surface control booster

Aircraft Hydraulics



CIVIL ENGINEERING

(*Continued from page 112*)

for successful coördination of the whole project.

The Institute's Department of Civil and Sanitary Engineering has in all turned out more than twenty-nine hundred graduates, many of whom have made substantial contributions to the engineering enterprises of this country. It is important to remember that these contributions have been made not only by professional engineers, but by those who have ventured into allied fields of endeavor, such as contracting, transportation and manufacturing. On account of its broad basis and general applications, a civil engineering education offers a foundation for success in many directions.

The real value of this education has been generally recognized as resulting from a thorough grounding in fundamental sciences. It is clearly these sciences which must be the basis for instruction in modern engineering, rather than the details of current applications.

During the present emergency this Department is partly occupied in giving instruction in Civil Engineering to Army and Navy personnel. The courses used for this purpose are necessarily abbreviated, but an effort is being made, nevertheless, to maintain the usual standards of instruction.

Graduates of the present undergraduate course in Civil Engineering have had a broad training in mathematics and science, surveying, structural theory and design, hydraulics, and foundation problems. They are well prepared to enter upon their professional careers as civil engineers, or into any occupation or business directly related to engineering or construction operations.

This course offers opportunities in the fourth year for specialization in Water Works and Sewerage, Transportation, or Water Power and Flood Control. It also includes group electives in Sanitary Engineering designed to give training formerly provided by the separate undergraduate course in that field.

Graduate studies leading to Master's or Doctor's degrees allow for further specialization, or for a broader and more liberal preparation for the whole field of civil engineering work.

Civil Engineering today has developed from a simple routine to a very comprehensive and complex profession. This should add much to its attractiveness, and to the calibre of the men who elect to follow it in the future.

JOE JENKS *Started Something*

JOSEPH JENKS labored for immediate results rather than distant glory when he made the dies for America's first coin, the "pine tree shilling", but he did much more than that.

This is the 300th year for the clumsy, crude, cooking pot which Joe Jenks designed and pulled from his sand mold and which still exists, the prized possession of the Hudson family in Lynn, Massachusetts. That pot is the first iron product made in America. Of American iron, it is the first product of America's first successful blast furnace. It is a pot full of American firsts.

It was in 1644, on a bank of the Saugus river midway between Salem and Boston, in Massachusetts Bay Colony, that "a guy named Joe" produced this three pound pot that boiled over, in 1943, into more than one hundred million tons of steel, a single year's output of the world's largest enterprise, the American steel industry. Last year, the American iron and steel industry employed over 625,000 men and women, and, with these men and women, paid over $700,000,000 in taxes. These steel-workers, with the steel and taxes to make more steel, are a main reliance of those other men and women who, on foreign battle fronts, are giving all to preserve a way of life that is its own reward.

With understandable pride, The Harrisburg Steel Corporation, with over ninety years of know-how in steelmaking, is producing in ever-increasing volume products of war and will continue to produce in the coming days of peace seamless and drop forged steel products that include seamless steel cylinders, liquefiers, pump liners, couplings, drop forged steel flanges, coils and bends and other products to the specifications of customers who range from the smallest to the largest user.

★

HARRISBURG STEEL CORPORATION

HARRISBURG, PENNSYLVANIA

SERVO — A MODERN SLAVE

(*Continued from page 126*)

or another wherever there is a point at which power available is not sufficient to perform a required function and must be amplified.

The most flexible servo-systems are those composed of electrical components. One such which deserves particular mention is the amplidyne or "well-bred short circuit" described in a previous issue of this publication.

Electronics have already and will be a most powerful tool in the development of servo-mechanisms furnishing the essentials of highly refined controllers for performance of complicated functions.

The invention of variable speed power transmissions has given a great impetus to mechanical servo design, since they satisfy the primary requirement of a servo-motor, to accommodate itself continuously to varying load and speed conditions. The displacement hydraulic variable speed transmission is the most important. Others include friction drives of the roller and disc types, and variable pitch chain and sprockets drives.

A simple error-controlled hydraulic displacement servo is shown in Fig. 7.

References:

1. H. L. Hazen, "Theory of Servo Mechanisms," *Journal of the Franklin Institute*, Vol. 218, No. 3, September 1934.

2. Notes on Fundamentals of Control Systems, C. R. Soderberg, 1940.

3. Design Factors Controlling Dynamic Performance of Instruments, by Draper and Bentley, ASMF Transactions, 1940.

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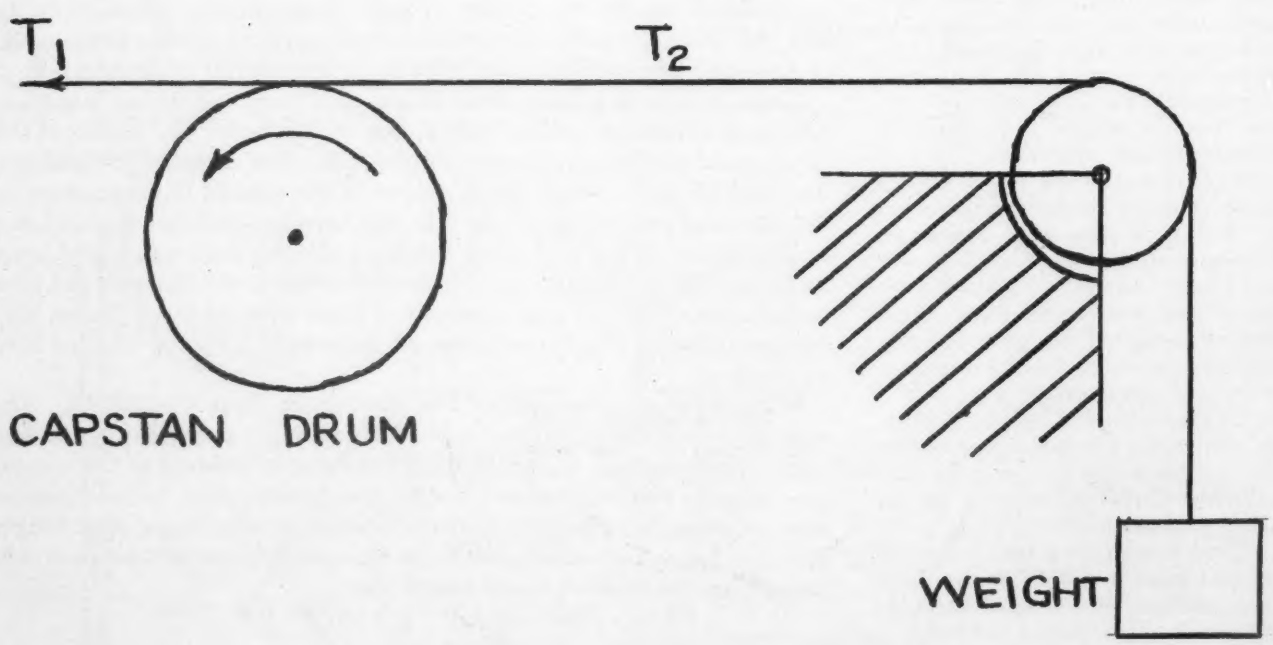
Fig. 6



Do You Know These

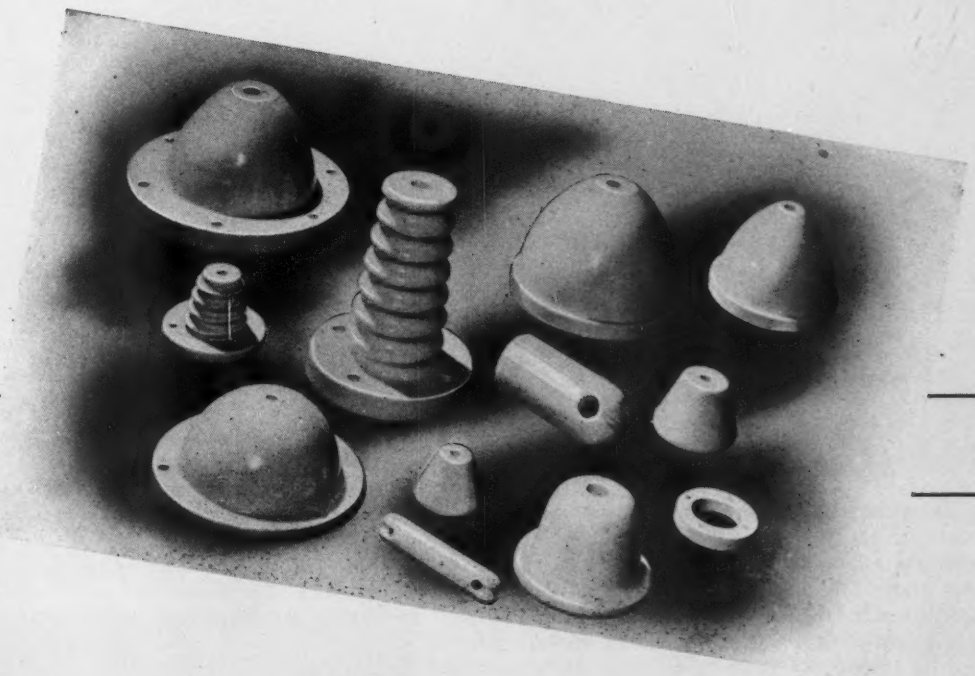
FACTS

ABOUT STEATITE

Steatite, or massive talc, is a magnesium silicate. When used as a raw material, it imparts unusual insulating properties to ceramic products. The name Steatite is generally used to describe ceramics which contain a preponderance of talc.

Massive talc is mined, sorted, cleaned and ground, and is used by the cosmetic industry as well as in ceramic manufacture. Talc of the highest purity is demanded for insulators, only ten per cent of the mined talc being suitable for the Steatite and High Dielectric Insulators of the General Ceramics and Steatite Corporation.

These insulators are used by leading radio and electrical manufacturers, not only in equipment for commercial use, but also for equipment built to the specifications of various governmental departments.



ARMY E NAVY

General Ceramics

GENERAL CERAMICS AND STEATITE CORPORATION STEATITE INSULATORS

AND STEATITE CORP.

KEASBEY **NEW JERSEY**

CHEMICAL WARFARE

(*Continued from page 119*)

the German Army, 2,280, or 2.9 per cent, died, while 1,806,275, or 43 per cent, of the 4,168,116 casualties produced by other weapons died. The corresponding figures for the American Army are as follows: Of the 70,752 gas casualties 1,421, or two per cent, died, and of the 187,586 casualties produced by other weapons 46,519, or 24 per cent, died. From these figures it is evident that the chance to live was considerably greater for the gas casualty. In addition he suffered less than one who was wounded, and also the gas casualty was not faced with a possibility of being maimed the rest of his life.

After the war, due to public opinion, the future of chemical warfare was uncertain. At the Washington Disarmament Conference in 1921 the representatives of the leading nations signed an agreement prohibiting the future use of chemical agents. This was not binding unless ratified by the nations concerned and France would not do so. In 1925 the Geneva Conference

The 4.2 inch chemical mortar in action. A white phosphorus shell bursts in background

Training Aids Division, Edgewood Arsena

adopted a gas protocol binding the signatory powers from the date of ratification. The United States was one of the fifteen nations who failed to ratify it. At the present time there is no international agreement forbidding the United States to use chemicals in war. From the past it appears unlikely that chemical warfare can be regulated by treaty.

Because of the existing conditions the military establishments of the leading nations maintained an active interest, in one form or another, in chemical warfare. That chemical agents will be used against any unprepared enemy has been demonstrated by the use of vesicants against the Ethiopians by the Italians and also by the Japanese against the Chinese. There are probably several reasons why chemical agents have not been used in Europe and these do not include any humanitarian considerations. In the first place the troops have protective equipment and are well trained in its use;

(*Continued on page 132*)

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ARE NEEDED BY

The American Red Cross

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$200,000,000

Is needed for the 1944 quota to maintain the work of the Red Cross

5,000,000

PINTS OF BLOOD

Must be donated to save American lives

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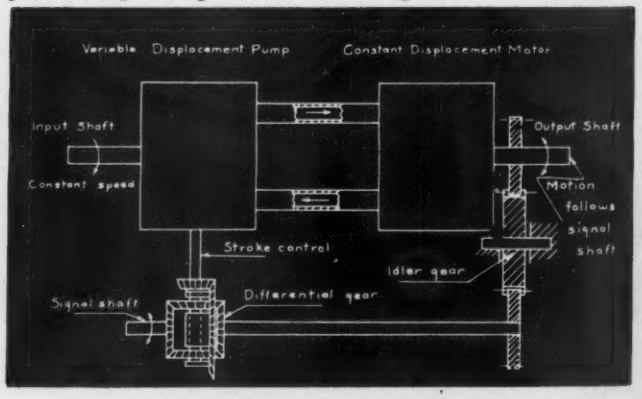
Give To Both Today!

Fig. 7. Torque amplifier or servo-circuit provides precise positioning in response to control signal



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On stratosphere flights it is this vital part of the Airco regulator which automatically controls the proper flow of life-sustaining oxygen. As flight altitude increases, it instantly increases the oxygen ratio. Like the supercharger, it has helped to push up the effective ceiling at which our war-planes may operate . . . making war-planes more deadly . . . air transports faster and safer.

This high altitude oxygen regulator is just one of many Airco products which—in addition to Airco welding and cutting torches and Airco and Wilson arc welding equipment—are contributing to the advancement of American aviation.

Similarly in every major industry—from shipbuilding to food packing—Air Reduction products and processes are helping to establish faster and better manufacturing techniques to meet the need for more and sturdier war goods. If you would like to receive our informative publication "Airco in the News," we shall be glad to send a free copy. Write to Mr. G. Van Alstyne, Dept. C. P., Air Reduction, 60 East 42nd St., New York 17, N. Y.

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CHEMICAL WARFARE

(*Continued from page 130*)

even the civilian populations of some of the countries are equipped with gas masks. Fear of reprisal may be another reason. The main consideration is probably the fact that the war has been one of rapid movement, while chemical agents are best used under stabilized or semi-stabilized conditions.

The methods and weapons of warfare are continually being modified. It is, therefore, necessary for the Chemical Warfare Service to carry on research and development. In time of peace contracts are made for the production of various substances and articles required in time of war. After war is declared it is often necessary to change these contracts due to improvements that develop during the progress of the war. The Chemical Warfare Service operates laboratories at Edgewood Arsenal and Massachusetts Institute of Technology.

The Chemical Warfare Service is responsible for the training of officers and enlisted men. At the Chemical Warfare School at Edgewood Arsenal the Service has trained not only its own personnel and that of the other branches of the Army, but it has also trained classes for the Navy. Since war was declared it has organized Civilian Protection Schools and trained many civilians. The graduates of these schools train groups in their home communities.

The Chemical Warfare Service maintains chemical troops for combat. These are organized according to the type of duties which they perform. The weapons companies are combat troops. They are organized into chemical battalions. The chemical laboratory companies are composed of highly trained men, a large number being Ph.D.'s; it is their function to analyze chemical agents used by the enemy and in this way help with chemical intelligence. The chemical decontamination companies are trained and equipped for handling major contamination problems. Chemical maintenance companies deal with such maintenance problems and salvage operations as derive from chemical combat troops. The chemical depot companies operate chemical warfare supply depots. Chemical processing companies have the function of impregnating clothing and equipment and thus increase the protection of the troops against vesicant agents. In addition to these units others have been and will be formed to fulfill special needs. The special staffs of the division and higher units include chemical officers and their assistants. Their duties are mainly advisory and administrative. The gas officers in smaller units are not members of the Chemical Warfare Service but are officers of that particular unit who have been designated for that duty by their commanding officer.

Prominent among the recent developments of chemical warfare are the so-called nitrogen mustards. Brigadier General Alden H. Wait (M.I.T. 1914), Assistant Chief of the Chemical Warfare Service for Field Operations, has said of them:

"The nitrogen mustards range from liquids to solids, from a colorless compound to a pale yellow, depending upon the specific mustard and its degree of purification. They are practically odorless or at the most have only a slight fishy smell. The smell is difficult to detect, especially if gas shells containing nitrogen mustard are mixed with high explosive shells."

The nitrogen mustards, like mustard gas itself, are vesicants or blistering agents, persistent, and casualty producing. They are particularly injurious to the eyes. However, the protective equipment which is effective against mustard gas protects the individual against the nitrogen mustards. This protective equipment consists of the service gas mask which adequately protects the eyes, the lungs and the portion of the face which it covers; impregnated anti-gas clothing which protects the skin against vapors and very small drops; and impermeable clothing which gives complete protection against the vesicants in either the vapor or liquid states.

In addition to this gas mask, the soldier carries a tube of protective ointment. He applies the ointment to any part of his body that has come in contact with vesicants as one of the first steps in the first aid treatment.

Although the nitrogen mustards are difficult to detect by means of their odor they are readily detectable by means of vesicant detector kits, paints, and liquids which have been developed by the Chemical Warfare Service.

(*Continued on page 134*)

The Esso smoke generator in action at Edgewood Arsenal

Signal Corps, U. S. Army

Imagine soldering metal to Glass !

HERE'S one for the book! The young lady is soldering metal to glass to make an important piece of electrical war equipment, and she doesn't have to be fussy about it either. She just solders!

The reason this can be done today is that some time ago Corning developed a method of firmly attaching a thin film of metal to glass, as a base for the solder. It was just one of many glass-metal problems that were once called "impossible."

Being ready with ideas has been the glass industry's greatest contribution to our war effort. That, and the ability to mass produce essential glass without delay.

Take Corning for instance. Here research found ways to mass produce essential optical ware. Insulators, aerial and naval navigation lenses, bulbs for electronic tubes, these and countless other war needed items are being turned out in vast quantities.

On the civilian front, Corning right now is supplying glass piping, and valves, nuts and bolts that resist chemical attack. Glass springs that apparently never wear out. Glass acid pumps that replace scarce metal alloys and give longer service in the bargain!

Glass isn't taking a back seat now, or after victory. Too many people are finding out something about its unusual qualities to ever let this happen.

They are discovering that glass is versatile. It has astounding strength. It can be shaped with great accuracy. It resists corrosion and abrasive wear. And they're finding out, too, that Corning knows glass, not only as a producer but as a developer of glass ideas.

In engineering, too, glass is a material with a brilliant future . . . In the years to come, keep your eye on glass! Corning Glass Works, Corning, N. Y.

CORNING
means
Research in Glass

CHEMICAL WARFARE

(*Continued from page 132*)

The nitrogen mustards are known to the Axis and there is reason to believe that they have large stores of these vesicants. However, the Allies are prepared to retaliate in kind should these agents be used against them.

One of the most important developments of the Chemical Warfare Service since World War I is the 4.2-inch chemical mortar. Since the United States entered the present conflict it has been improved. It is the principal weapon of chemical troops and one of which they may be justly proud. It is a light mobile weapon and very accurate. It fires gas shells, smoke shells, and high explosive shells. Smoke shells filled with white phosphorus are employed either for screening, since the smoke formed has the greatest obscuring power of any of the smokes, or for casualty effect caused by the burning particles of white phosphorus, or for a combination of the two effects. The use of high explosive shells is comparatively new and immensely increases the value of the 4.2-inch chemical mortar.

While toxic agents have not been employed by our troops, and will not be unless the enemy uses them first, our chemical units are present at the various fronts. They have actively participated in the Tunisian, Sicilian, and Italian compaigns, giving support by use of white phosphorus and high explosive shells against pill boxes, tanks, gun emplacements, and personnel. Although a great deal of this has been for casualty effect, smoke has been used to hinder enemy observation. It has also been used to assist our troops in advancing over open terrain when the enemy possessed excellent fields of fire, for by placing smoke upon an enemy firing line, our troops are given a fire superiority of four to one.

Sometimes it is desirable to project smoke by a means other than chemical mortars. Smoke pots may be employed if the wind has the proper direction and velocity. H. C., hexachlorethane, smoke pots may be used on land and floating smoke pots upon the water. FS smoke, sulfur trioxide in chlorsulfonic acid, has been successfully employed by spraying from tanks under the wings of fighter planes. In screening large important areas such as military reservations, cities, and harbors, the Chemical Warfare Service mechanical generator has been very effective. This generator, which has been developed since this country entered the war, produces a dense artificial fog which has a secret composition. Chemical Warfare personnel are enthusiastic over their mechanical generator.

A type of smoke which civilians find very fascinating is the colored smokes. The particles of these smokes are actually colored. These smokes are employed by ground troops to signal supporting planes, the message conveyed depending upon the color which is used.

Civilians and especially those who have been interested in Air Raid Warden duties, have heard much about incendiary bombs. The Chemical Warfare Service has manufactured a variety of sizes of several types, including magnesium, thermite, and solid oil bombs, which upon impact produce very high temperatures. These bombs have been used all over the world.

Space does not permit further discussion which would include modified gas masks for special types of duty, improved fuel for flame throwers, and other interesting items. However, it is hoped that this article will give the reader a better understanding of the Chemical Warfare Service.

FACE POWDER GOES TO WAR

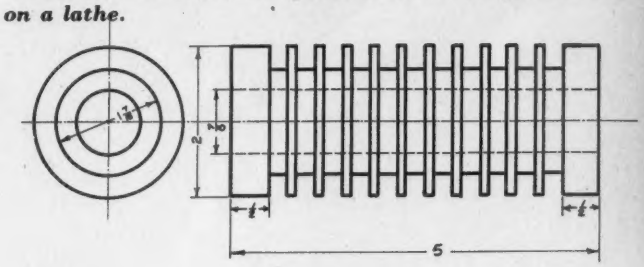
(*Continued from page 114*)

is too quick, these crystals are not obtained, and if it is too slow, the crystals are too large. The strength of the material and electrical properties depend upon this crystal formation. Each body has its best heating cycle, which is based on its crystal structure formation.

The final pieces are tested for conformity to specifications: overall size, within given tolerances, wall thicknesses, hole sizes, taps and threads, strength, and glaze. If a piece is over size it can usually be ground, small holes can be enlarged, damaged threads can often be ground and a poorly glazed article can be reglazed and fired again.

TYPICAL EXTRUDED PART

This part is extruded in a long hollow cylinder, outside diameter 2 inches and inside diameter ⅛ inch. Then it is machined to size, the spaces between the fins turned on a lathe.



The finished product should have, for best results, a dielectric constant less than 7, a loss factor less than 1.00 per cent, a dielectric strength not less than 150 volts/mill and a volume resistivity from 1×10^6 to 1×10^8 ohms per cubic centimeter. A test sample should be able to withstand at least twenty thermal-shock cycles. One cycle comprises twenty minutes. The sample is immersed for ten minutes in a cold bath not higher than 4° C. and then for ten minutes in a hot bath not less than 96° C. A piece that meets these specifications is now ready for assembly into integral parts of radios, high frequency instruments, and other electrical units.

Edgewood Arsenal, Md. Four-hundred-gallon decontaminating apparatus in use. *Signal Corps, U. S. Army*

Plastics Will Mean Better Homes

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EVEN TODAY, plastics men can vision a bathroom with practically everything in it made of plastics or containing plastics in some form. Imagine such a bathroom, costing less to manufacture, to ship, and to install, delivered *as a unit* to your home!

The raw materials to make better homes with more bathrooms and finer kitchens come true are *in existence today* . . . in VINYLITE and BAKELITE resins, and plastics made from them.

BAKELITE resin-bonded plywood, like that from which planes and torpedo boats are made, can be used to make floors, walls, ceilings, and furniture.

The type of plastic film used in waterproof, chemical-resistant food bags and rifle covers can be fabricated into mildewproof shower curtains. VINYLITE resins can also be made into rot-resistant floor coverings that can be walked on millions of times *without showing appreciable wear!*

Our engineers know from the record of VINYLITE plastic-coated life raft sails, sleeping bags, and life preservers, that VINYLITE plastics and compounds can be used in the future to bring you wall coverings, window curtains, and furniture finishes that will outlast anything now available.

Under heat and pressure, VINYLITE and BAKELITE plastics can be molded into numberless useful forms. Experience gained in molding war equipment will help to bring you such things as molded plastic furniture which will be lighter, easier to move, easier to keep clean!

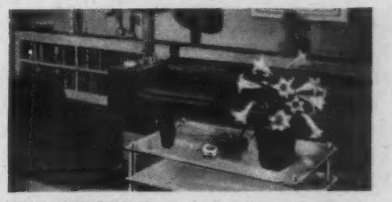
Spun plastics made from vinyl resins are resistant to rot. Right now, such plastics are used for making jungle hammock ropes and vital chemical filters. They also can be fashioned into draperies, upholstery, stockings, and other articles of clothing ...sun-proof, water-proof, and moth-proof!

VINYLITE and BAKELITE resins and plastics, and many new techniques for using them, are peacetime research achievements of CARBIDE AND CARBON CHEMICALS CORPORATION and BAKELITE CORPORATION, both Units of UCC. Fabricators converting these raw materials into finished articles are making them mean more and more to you.

GREATER SAFETY! Improved electrical wiring insulation that *will not support flame* can be made from several VINYLITE plastic compounds. Such wiring, now employed in vital circuits of warships, will some day provide greater safety in the home.

MORE BEAUTY! New *washable* water paints based on BAKELITE resins, will bring new beauty to homes. These paints are inexpensive . . . and *easy to apply!*

LESS EXPENSE! Use of BAKELITE molding plastics in making washing machines, refrigerators, and many other household devices and fixtures can mean lower-priced, longer-lasting equipment for you.



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PLASTICS
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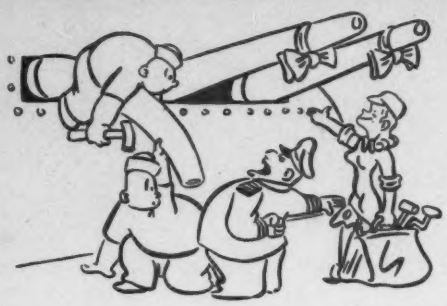
"BEAUTIFUL" WORKING QUALITY



It *was* a man's world. Then came the war! Then came the call for workers of the fair sex. Thousands of 'em—"God-Bless-'em." Well, we're neutral in this battle of the sexes for whether you're a big rugged he-man ruling bold black outlines for a dreadnaught or a choice bit of femininity putting the finishing touches to a design for a dainty dial, Higgins will match your skill with "Beautiful" working quality.

SEND FOR COLOR CARD

HIGGINS INK CO., INC.
271 NINTH ST., BROOKLYN 15, N. Y.

BIRTH OF A BOMBER

(*Continued from page 123*)

united and form the major assemblies. Each assembly is made as complete as possible, and it is at this point that most of the wiring and rigging is done. Then the major sections are brought by truck or crane to final assembly, where the nose is spliced to the center portion and the tail fitted on. Then the wings are attached, landing gear and offensive armament installed, control wires rigged, power plants installed, and the remainder of the wiring and tubing connected. The finished plane is then rolled out of the factory, and turned over to the ground crew. If an experimental plane has not already been built and tested, the first plane that comes off the assembly line must undergo extensive flight testing. Any changes indicated by the tests will be incorporated into the planes that are moving up the assembly line.

As each plane comes off the line it is turned over to the crew chief and his mechanics for ground testing. They put gas into the fuel tanks and check for leaks. The oil tanks and the hydraulic system are checked as are all engine accessories, like throttle, mixture, and governor controls. Next the starter system and manifold intakes are installed, and the carburetor and supercharger attached. The carburetor is flushed for "air locks," and the primer line cleared of all foreign material.

The ship is then ready for ground testing. The engines are turned over by hand three times to make sure that no oil was left in the lower portions of the cylinders. The plane is checked fore and aft and the parking brake set. The crew chief and an inspector climb into the cockpit to witness the initial run of the

Flight line from control tower

motors, but first the fuel valves must be set, and all of the instruments — tachometers, ammeters, and voltmeters — examined.

The starter is switched on, and the engine given a trial run. During this run, all of the instruments and apparatus connected with the engines are examined, then the engines are shut off, and the ground test stamped off as O.K.

The bomber is now in pre-flight status, and it is at this point "packed" with all the auxiliary equipment not bolted to the plane. This includes fire extinguishers, life rafts, and the like. The guns are bore sighted, and all armament checked. Then engineers from the flight test section inspect the ship, and declare it ready for a test flight.

A company pilot takes the plane up for two and a half hours, checking flight instruments, controls, and gear in general. He marks off unsatisfactory items on a check sheet that he carries, and these are quickly taken care of by the flight line mechanics. The plane is then turned over to the Army for acceptance. An Air Corps pilot takes the bomber up and puts it through its paces. On his acceptance, the Ferry Command takes over the plane, and the bomber soon arrives at its destination.

The manufacturer does not exit just yet, however. Civilian maintenance men from the factories go out to the front lines and, acting as technicians, teach the Army ground crews how to handle the planes and how to repair them. The assembly line back in the factory is keeping right up with the front lines too, for every improvement suggested by experience in battle and every effective new invention must be incorporated into the planes moving up the assembly lines.

Thus the whole plant is kept busy, changing designs, retooling dies, and making new tools, and this is one of the main reasons for American plane superiority. Our factories stand behind the men at the fighting fronts.

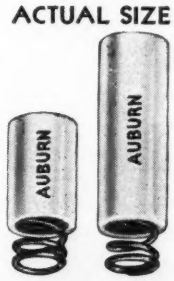
Cover picture courtesy Signal Corps, U. S. Army
Title page picture courtesy U. S. Steel
Frontispiece courtesy Westinghouse

Winging to Victory

With Our Fighting Aircraft

Aircraft Connectors

ACTUAL SIZE



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On every far-flung battle front Auburn Connectors make the *CONTACT* that really "keeps 'em flying!"

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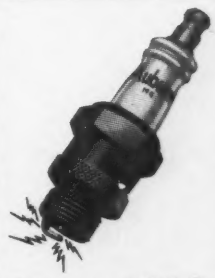

Since 1910 manufacturers of Auburn Spark Plugs for cars, trucks, busses, tractors, etc.

AUBURN SPARK PLUG COMPANY, Inc.
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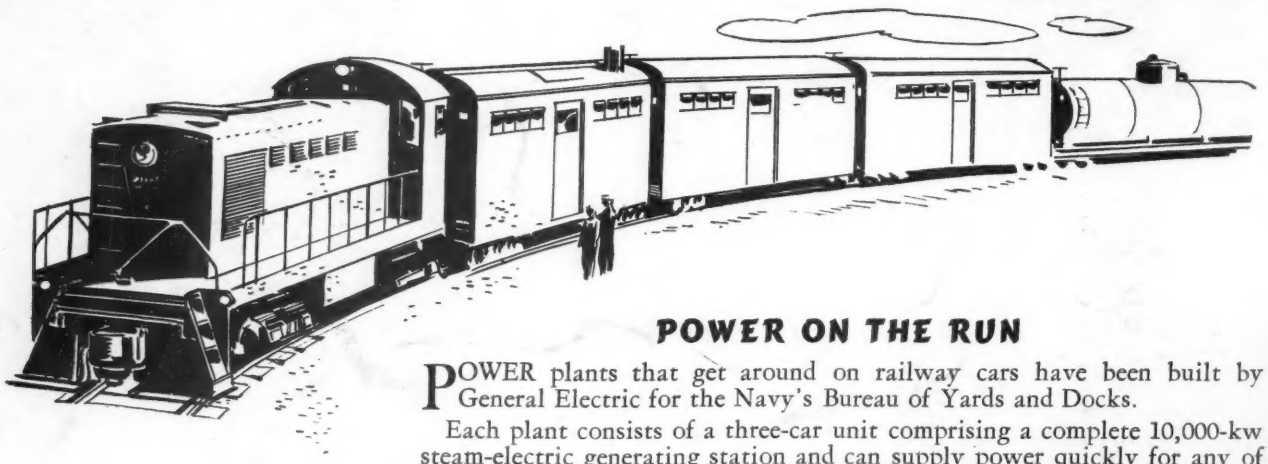
GE Campus News

RESEARCH AND ENGINEERING KEEP GENERAL ELECTRIC YEARS AHEAD



POWER ON THE RUN

POWER plants that get around on railway cars have been built by General Electric for the Navy's Bureau of Yards and Docks.

Each plant consists of a three-car unit comprising a complete 10,000-kw steam-electric generating station and can supply power quickly for any of the Bureau's many projects. Engineers estimate that these power plants can be "put on the line" within 24 hours after they are shunted on to a siding.

Although the units in themselves are unique, the apparatus involved is of the same type used in regular central station and industrial power plant installations throughout the country.

MACHINE OF MERCY

A HYBRID electric washer and water heater, devised by G-E workers, speeds and improves the Sister Kenny treatment of infantile paralysis. This treatment employs the application of hot damp packs to the patient to relieve pain and reduce muscular spasms, and the washer provides an improved way of heating and wringing the heavy woolen cloths used.

In the bottom of the tub, which does not have an agitator, is a Calrod immersion heating unit that can bring the water to a boiling point, permitting the use of the machine for contagious cases.

TEMP-TURB

A G-E engineer has ironed out the problem of temperature control and windshield defrosting in planes. His solution is an ingenious application of the bimetallic thermosensitive element used in automatic household irons.

This device, called the Temp-Turb, which regulates air temperatures for cabin warming and windshield defrosting, is now being installed in Havoc A-20 bombers.

The operation of the Temp-Turb requires no external source of power other than that obtained from the velocity of air flowing through it, on the windmill principle.

Hear the General Electric radio programs: "The G-E All-girl Orchestra" Sunday 10 p.m. EWT, NBC—
"The World Today" news, every weekday 6:45 p.m. EWT, CBS.

GENERAL ELECTRIC

953-76-211

192,000 employees of the General Electric Company are on their jobs producing war goods and buying over a million dollars of War Bonds every week to hasten victory.

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